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HIGHWAY METRICATION

Vol. 1. Tasks 1, 2, 3, 4 and Apercu

D. G. Meacham and others

April 1975
Final Report

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FEDERAL HIGHWAY ADMINISTRATION
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16. Abstract

The study purpose is to identify various problems which are likely to arise during highway metrication and to prepare a detailed plan for research aimed at solving conversion problems.

Investigations reveal a need for an early selection of the metric units to be used, the vital importance of early metrication of specifications and standards, and the absolute necessity of coordination of metrication activities on the national level.

This volume contains a discussion of pertinent information related to highway metrication obtained from literature searches, interviews, and correspondence. Problem areas are defined and a program for further research is presented.

This volume is the first in a series. The others in the series are:

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PREFACE

On March 29, 1974 the Ohio Department of Transportation (ODOT) was awarded a research contract by the Federal Highway Administration (FHWA), U.S. Department of Transportation, to conduct a study entitled "Highway Metrication". The objectives of this study are to:

1. Identify various problems which are likely to arise as the metric system is used more frequently in highway design, construction, operation, maintenance and inventory.

2. Prepare a detailed plan for research aimed at solving conversion problems.

Subsequent to entering into the contract with FHWA, the Ohio Department of Transportation awarded a subcontract to the Ohio State University (OSU) to assist ODOT in fulfilling its contract. Primarily, OSU has performed the Literature Review and Analysis portion of the study but also has advised and assisted ODOT in executing other portions of the study.

The research work was performed by the following individuals:

For the Ohio Department of Transportation:

- Principal Investigator and Project Manager
  Mr. Donald G. Meacham, P.E.

- Associate Investigator
  Mr. Lewis Besch, Jr., P.E.

- Support Engineers
  Mr. John O. Hurd, P.E.
  Mr. Thomas B. Culp, P.E.

- Research Associates
  Mr. James M. Golding, E.I.T.
  Mr. Michael E. Smith, E.I.T.

·Other engineers, draftsmen and typists as required.

For the Ohio State University:

·Principal Investigator
Dr. Alfred G. Bishara, P.E.

·Associate Investigator
Dr. Slobodan Mitric

ACKNOWLEDGMENTS

The researchers for this project were assisted by many members of the Ohio Department of Transportation and other organizations. Lack of space prevents a detailed listing of all who provided information and who were involved in the actual preparation of the report. Needless to say, without their assistance and contributions this report could not have been prepared. Several individuals and bureaus of ODOT contributed greatly to the successful completion of the research project and merit separate recognition. Among these were:

From the Office of the Director of Transportation

Mr. Thomas M. Major, Assistant to the Director for Special Projects. Mr. Major coordinated all activities between the research project's study team and the Director's Office, the Federal Highway Administration, the Ohio State University, various ODOT Bureaus and Transportation Districts 5 and 10.

From the Bureau of Public Information

Miss Ginny McDaniels. Miss McDaniels coordinated the Public Information (Phase 4) and Public Reaction (Phase 5) Phases of TASK 2 and provided information for and assisted in the preparation of the report for these two phases.

From the Bureau of Traffic

Mr. Thomas B. Culp, P.E., Research Program Engineer. Mr. Culp supervised the execution of the Public Use and Adaptation Phase (Phase 3) of TASK 2 and wrote the final report for this phase. Many members of the Bureau of Traffic and that bureau's Research and Development Section made significant contributions towards the successful conduct of this phase. Among these were Messrs. Raymond F. Lindsay, Eagan L. Foster, Jack M. Schlesinger, Donald E. Weppler, Eldon Henderson and Daniel Spence who accomplished the majority of the data collection and data reduction

efforts, Messrs. Charles T. Koerner and Mohammad M. Khan who accomplished much of the data analysis, and Mrs. Betty J. Alton who prepared the manuscript for publication. Special thanks are given to Messrs. Wallace C. Richardson, Thomas J. Foody, and Michael D. Long for their valuable assistance to Mr. Culp in the design of this phase of the project.

<u>From the Transportation Field Districts</u>

Mr. Victor H. Wolff, P.E., District 10 Design Engineer. Mr. Wolff was in charge of the design of Metric Project No. 2 (HOC-93-0.14) and assisted in the coordination of the efforts of the Metric Study Team in District 10. Additionally, he submitted a written report detailing the design activities of his office.

Mr. Richard F. Sachs, P.E., District 5 Design Engineer. Mr. Sachs was in charge of the design of Metric Project No. 3 (PER-188-03.84) and assisted in the coordination of the efforts of the Metric Study Team in District 5.

<u>From the Bureau of Roadway Design, Hydraulics Section</u>

Because the Metric Research Project Manager is assistant head of this section, it bore the greatest responsibility in the execution of the research project and in the preparation of all reports. The following individuals spent much or part of their time on the metric research project.

Mr. John O. Hurd, P.E., Assistant Hydraulics Research Engineer. Mr. Hurd assisted throughout the accumulation of data and preparation of reports. He assisted in interviewing all individuals involved in providing information for TASK 2 and wrote drafts of portions of the Interim Report and portions of TASK 2 and all of TASK 3.

Mr. C. Gene Pettit, P.E., Hydraulics Special Projects Engineer. Mr. Pettit assisted in the design of the Final Report, assisted Mr. Hurd in accomplishing TASK 3 and helped

proof-read manuscript.

Mr. Robert L. Dickson, P.E., Hydraulics Structural Engineer. Mr. Dickson assisted in the analysis of data for Phase 5, TASK 2 and proof-read the majority of the typed manuscript.

Mr. L. Vincent Bash, Engineering Technician. Mr. Bash prepared all illustrations and tables and coordinated the printing of the Interim and Final Reports.

Mrs. Miriam F. Grimm, Clerk-Typist. Mrs. Grimm typed most letters of correspondence, the monthly progress reports and portions of the Interim and Final Reports.

Miss Leslee M. Schultz, Clerk-Typist. Miss Schultz transcribed most of the tapes made while conducting interviews, typed most of the Interim and Final Reports, and assisted in the analysis of the data for Phase 5, TASK 2.

Special Thanks are given to Mr. E. J. Schaefer, Engineer of Roadway Design and Mr. Neil J. McMillen, Engineer of Hydraulics for their moral support and for permitting the extensive use of the Hydraulic Section's personnel on this project.

Special Thanks are also given to Mr. Ernst Lange of the National Aeronautics and Space Administration for his invaluable assistance to members of the research team in the literature search effort.

INTRODUCTION

The adoption of the metric system of weights and measurements is spreading rapidly throughout the world. Nearly every country either has changed or is about to change to it. The continent of Europe uses it exclusively; the United Kingdom, all the chief British Commonwealth countries and South Africa have changed or at the moment are changing over to it. For many years the United States has pondered the idea of converting its system of weights and measures from the customary American system to the metric system. Studies as early as 1821 indicated that the metric system approached "the ideal perfection of uniformity applied to weights and measures" but concluded that the time was not right for it and that it would be better to wait until a uniform international system could be worked out. In 1866 Congress passed a bill legalizing the use of the metric system but also retaining the customary American system, which had been adopted from Great Britain in the colonial days.

Many attempts were made over the years to change the United States to a metric standard country but none resulted in a law being passed. Meanwhile other countries were adopting the metric system, starting with France which made it compulsory throughout that country in 1840. Eighteen countries, including the United States, subscribed to the Convention of the Metre in 1875 to establish and preserve international standards of length and mass. In 1960, the General Conference of Weights and Measures, which meets under the Convention, agreed at its 11th Conference to promulgate an "International System of Units" (frequently described as the "Systeme International" or "SI"). This is the current version of the metric system. In 1968 the USA Congress passed a law directing that a U.S. Metric Study be undertaken, and reports from that study were submitted to Congress in 1971. This study involved input from all facets of American life and concluded with the recommendation "that the United States change to the International Metric System deliberately and carefully". Currently, bills are pending in the Congress to convert the U.S. to the International System of Units (SI).

Progress to metrication cannot be a haphazard affair, left to individual whim and decision. If that were to happen it could cause confusion throughout industry and would present untold difficulties to all concerned, particularly the consumer. It is in everybody's interests therefore to ensure that it takes place in a well-ordered and properly-regulated manner. The Federal Highway Administration (FHWA) recognizing this fact decided to cause an in-depth study to be made into the problems that would confront the highway industry when, and if, it converts all of its functions to the metric system (note: throughout this report, "metric system" and the "International System of Units", SI, are used interchangeably). After a series of negotiations, the FHWA entered into a contract with the Ohio Department of Transportation (ODOT) to perform research in the field of highway metrication; and charged ODOT with the task of enumerating unsolved conversion problems, evaluating whether these problems are solvable and detailing a program of further research studies. Subsequently, ODOT engaged the Ohio State University (by subcontract) to assist in the Study. The FHWA informed ODOT that this study was to be nation-wide in scope and should provide guidelines by which state departments/divisions of highways can efficiently and economically make the transition to the metric system.

To accomplish the objectives of the study, the research project was divided into the following tasks:

Task 1. Literature Review and Analysis.

a. Review any available literature on other metrication programs as they pertain to highway design, construction, operation, and maintenance.

b. Contact the British Ministry of Transport (now Department of Environment) to ascertain likely problem areas in effecting a change to the metric system and ways of dealing with them.

c. Prepare a summary report of pertinent evaluation studies and experience elsewhere in the world.

Task 2. Summary Report of ODOT's Five Phase Metrication Program.

These five phases are:

- PHASE I - Design of two construction projects using the metric system.

- PHASE II - Construction of the two metric projects designed under Phase 1 in which the metric system is employed in layout, inspection, testing and project documentation.

- PHASE III - Evaluation of motorist response to metric informational signs which have been installed on Interstate highways in Ohio.

- PHASE IV - Distribution of a metric information brochure explaining the advantages of using the metric system and providing conversion tables for the motorists.

- PHASE V - Observation and analysis of public reaction to the metric signs.

Task 3. Identification of Problem Areas.

a. Identify problems in conversion to and use of the metric system in highway planning, location, design, construction, quality control, maintenance, inventory and traffic control.

b. Enumerate alternate solutions to these problems and analyze the feasibility of implementing such solutions.

Task 4. Program for Research.

Develop a detailed plan for research needed to support a smooth and effective conversion from the English to the SI measurement system in the various phases of highway

operations (planning, layout, construction, traffic control, maintenance and inventory).

This final report completes the requirements of the research project "Highway Metrication".

An Interim Report was issued in August of 1974 and summarized the work performed as of July 15, 1974 on TASK 1 and TASK 2 of the study. The Final Report is complete in itself excepting for the design phase of TASK 2. The appendixes related to the design of Metric Project 2 (HOC-93-0.14) have not been reproduced herein. However, the pertinent information obtained related to that activity has been included in the text of this report.

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VOLUME 2

TASK 1

Literature Review and Analysis

Chapter 1: Introduction

The main activity of this project has been to search for, study and evaluate information directly or indirectly concerned with introduction of the International System of Units (SI) to the field of highway transportation engineering.

The sources of information, whether they be articles, books, pamphlets, letters or interviews are mainly from organizations and individuals from certain foreign countries, which have recently undergone metrication or are still in the process of metrication, e.g. Great Britain, Australia and New Zealand. It is believed that the materials reviewed and evaluated in this report will be of help to persons and organizations involved with highway metrication in the U.S.A., which cannot be far behind, to anticipate problems which they might encounter, and to use means of solving or preventing these problems.

This report on the results of Task 1 is organized in the following way: Chapter 2 briefly describes the modes of information search employed in this project; Chapter 3 reviews the information gathered, grouped in ten sections.

Appendix A lists sources of information used for this project. Section 1 contains lists of libraries, computerized searches and other metric projects contacted. Sections 2, 3 and 4 contain complete lists of all organizations with which we made an attempt to correspond (professional organizations, manufacturers of highway equipment and materials, governmental organizations). Section 5 contains a list of several references and bibliographies that were used in the literature search.

Appendix B: (Section 1) presents an annotated Bibliography of materials pertaining directly to highway metrication

and Section 2 presents summaries of personal interviews.

Appendix C presents the comprehensive bibliography of all items pertaining to this study which were found in the process of literature search.

Chapter 2: Search for Information

Three main modes of search for information were utilized: search and study of published literature available in libraries, from organizations and private individuals; correspondence with persons and organizations involved in metrication or likely to become involved; and personal interviews conducted in Great Britain, by the combined ODOT/OSU team of researchers, during the month of August 1974.

2.1 Literature Search

The search for metric information made major use of standard reference works, computer information banks, the Ohio State University Libraries, and other libraries through Ohio. A complete listing of these three types of sources is given in the Appendix A. Early in the project, letters were sent to various libraries in Ohio, nine of which responded with a bibliography of their metric holdings. Some of these sent us materials as well, while others indicated an interest in the project but could supply neither bibliographies nor materials, due to staff shortages. We visited some of these libraries (see Appendix A for a listing).

Three computer banks were searched during this project. We initiated the search of Mechanized Information Service (MIC) of the Ohio State University Libraries, which contributed many items to the general bibliography on metrication (Appendix C). The Computer bank of the Highway Research Information Service (HRIS) in Washington, D.C. contained little material of interest to this project. Finally, through kind effort of our British colleagues, computer search was done at the Transportation and Road Research Laboratory, Crowthorne, England; this search produced a number of references that we later made use of.

The largest part of our information was obtained through published bibliographies and general references. A special mention must be made of NASA's Information on the Metric System and Related Fields by E. Lange, L. Sokol and V. Antoine, Sixth Edition, Feb. 1, 1974. We obtained this publication halfway through the project and decided to list in our comprehensive bibliography only those items which were not already contained in the NASA Bibliography. In addition to making our task on the comprehensive bibliography easier, it also provided us with a number of references for the annotated bibliography (Appendix B). The principal author of NASA's document, Mr. Ernst Lange, was especially helpful and personally directed us to some useful materials.

2.2 Correspondence

Important additional information was obtained by writing letters to various domestic and foreign agencies whose activities are in the highway field or have some influence on it, especially in connection with metrication. We contacted 52 agencies and received replies from 38, in some cases accompanied by literature which proved quite valuable. Various governmental agencies from Great Britain, Australia, New Zealand and Canada were very cooperative (for a complete listing of their names see Appendix A).

In addition, we wrote 84 letters to U.S. manufacturers of highway construction equipment, 37 of which replied; we wrote 20 letters to U.S. producers of highway construction materials, 11 of which replied. Names of all these organizations are listed in Appendix A.

2.3 Interviews

Three researchers from this project visited Great Britain at the end of July, 1974. These people were: Mr. Donald Meacham, Principal Investigator and Project Manager, Mr. Lewis Besch, Associate Investigator, both from ODOT, and Dr. Alfred Bishara, Principal Investigator from the Ohio State University research team.

Between July 22 and August 2, 1974 they interviewed a number of people connected with metrication from 15 different British agencies and companies. Persons interviewed ranged from agency officials down to site operatives. Interviews were taped. Selected portions of these tapes were transcribed and provided us a significant amount of information in areas where the literature was incomplete. A complete listing of agencies and companies where interviewing took place is given in Appendix B.

Chapter 3. Review of Information Gathered

3.1 Introduction

This chapter has nine sections following this introduction. The first section, Metric Units, is to serve as a reference for some discussions in later sections. The second section, Metrication Methods, is primarily a report on the methods used in foreign countries to convert to the metric system with emphasis on Great Britain's experiences. The third section, Conversion Timetables, reproduces national (foreign) timetables that are relevant to highway metrication for conversion to the metric system. The fourth section discusses Metrication of Standards and Specifications. The next two sections deal with the important ancillary subjects of Metrication of Highway Materials and Metrication of Highway Equipment. The seventh section, Metric Training of Personnel, discusses education and training of all levels of personnel. The next section, Costs and Benefits of Highway Metrication, reviews the information gathered concerning this significant aspect of metrication. The last section is titled, Miscellaneous, and discusses those items which did not readily fit into any of the preceeding sections.

This chapter should be read together with Appendix A, "Source of Information", and Appendix B, "Annotated Bibliography on Highway Metrication". References are frequently made to articles, documents, letters or interviews listed in these appendices in the following way: (B, 1, 10) means that the source of information is listed in Appendix B, section 1, item 10.

3.2 Metric Units

There are a number of metric systems used in the world. One of these systems, the cgs system, uses the centimeter, the gram and the second for base units. This system worked well for scientists until the units were found to be incompatible with electric units (such as ampere). Thus, the MKSA system, based on the metre, kilogram,

second and ampere was proposed. In 1960, the 11th General Conference on Weights and Measures expanded the MKSA system and recommended the universal adoption of a complete, coherent measurement system to be known as the International System of Units (abbreviated to SI in all languages). Countries which soon intend to switch or have recently switched to the metric system have chosen SI as their system of measurement. These countries include Great Britain, Australia, Canada, New Zealand, Rhodesia and South Africa. Also, many European countries using various types of metric units are announcing their intentions to switch to the SI. Therefore it is likely the United States will use the SI metric system and it is that system which is described herein.

Like any other measurement system, the SI consists of: (a) a small number of base units and (b) any number of derived units obtained by performing arithmetic operations on the base units and multiplying by proportionality constants.

The seven base units of the SI are:

(1) metre (m) -- the unit of length
(2) kilogram (kg) -- the unit of mass
(3) second (s) -- the unit of time
(4) ampere (A) -- the unit of electric current
(5) Kelvin (K) -- the unit of temperature
(6) candela (cd) -- the unit of luminous intensity
(7) mole (mol) -- the unit amount of substance

There are two dimensionless SI units which are called supplemental units. These are the radian (rad) for plane angles and the steradian (sr) for solid angles.

Derived SI units are found by multiplying or dividing the base units. Note in these examples that the implied proportionality constant is 1 (i.e., SI is a coherent system of units).

unit of velocity = m/s or $m \cdot s^{-1}$ (no special name)
unit of acceleration = m/s^2 or $m \cdot s^{-2}$ (no special name)
unit of force = $kg \cdot m/s^2$ or $kg \cdot m \cdot s^{-2}$ = N (newton)

unit of energy = N·m = J (joule)
unit of power = J/s = W (watt)
unit of stress = N/m^2 = Pa (pascal)

In order to facilite the expression of very large or very small results of computations, several approved prefixes may be attached to any base, supplemental or derived SI unit. These prefixes are as follows:

Prefix	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
*hecto	h	10^{2}
*deca	da	10^{1}
*deci	d	10^{-1}
*centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

For the field of applied technology, which includes all engineering, the International Standards Organization (ISO) recommends that the starred prefixes be avoided as much as possible, and that prefixes representing 10 raised to powers which are multiples of three be used. The purpose of this advice is to facilitate computations (by making it easier to locate the decimal marker) and discovery of errors. This advice may sometimes be suspended for expedience. For example, the difference between a mm^3 and a m^3 is so large (they differ by a factor of 10^9), that the use of the litre, as a special name for a cubic decimetre, is acceptable.

Similar methods of expressing SI units and numbers are being accepted in most of the countries listed earlier. A discussion of these methods follows.

When writing symbols for units and prefixes, careful attention must be paid to whether the symbols are upper or lower case letters. All symbols for prefixes are lower case except tera (T), giga (G) and mega (M). Note that MN (meganewton) is one billion times larger than mN (millinewton), but the only symbolic difference is the upper or lower case letter. Symbols for units are always lower case, unless that unit is named after a person. All names of units when written in full, start with a lower case letter (unless it is the first word in a sentence). Examples are: metre (m), pascal (Pa), newton (N) and second (s). When symbols are raised to a power, the exponent is applied only to the symbol, not to the number preceeding it. For example: $5m^2 = 5(m)^2 = 5(mxm)$ or 5 square metres (<u>not</u> 25 square metres).

Other rules for symbols: Litre and tonne should be written in full as their symbols can be confused with 1 and ton. Symbols should not be followed by periods, except at the end of a sentence. Plural symbols should not have an attached "s", e.g. 10 kg and <u>not</u> 10 kgs. Units written in full should never be hyphenated, even at the end of a line. Products of two symbols should be indicated by a dot, e.g. m·s. The dot may be ommitted if no ambiguity results, e.g. kgm.

Certain conventions have also been established for writing numeric values. The first is that units should never be mixed, e.g., write 49.37 m and <u>not</u> 49 m 37 cm. Numerical values should be kept within 0.1 and 1000 by choosing the appropriate prefix, e.g. 1.7 km and <u>not</u> 1700 m. Zeros should be inserted before the decimal marker for all numbers less than one, e.g., 0.1 mm and <u>not</u> .1 mm. A space should be left between a numerical value and a symbol.

Some issues continue to be debated. In most European countries, the comma is used as a decimal indicator, while long strings of digits are separated by dots into groups of 3. For example 3.000,000.0 in Europe means 3,000.0000 in the United States. Most countries switching to the SI have decided to separate groups of three digits with a space and disagreement exists as to what symbol should be used as a

decimal marker. In Great Britain, Australia and New Zealand, the dot is still being used as a decimal marker. Britain attempted raising the dot but later went back to the dot on the line (B, 1, 2). In South Africa and many of the smaller countries such as Rhodesia, the switch to the decimal comma is being or has been made. There are many good arguments for the comma, but in large industrial countries, the switch could precipitate much confusion.

Much controversy exists over how strictly one should adhere to the SI and this will be discussed in the following sub-sections. It should be clear from the outset that if the system is to be used by all science and technology, some sacrifices (and compromises) have to be made by any one individual branch of science and technology.

3.2.1 Units and Rules for Use in Design

Discussion found in the literature on this topic centers on the units used for length, force and stress. Some authors claim that strict adherence to SI units would result in unwieldy numbers in typical engineering calculations, and it is suggested that the "proliferation of named units and values now used in engineering calculations did not all derive from some arbitrary association," but from better results using convenient numbers (B, 1, 11).

Controversy on length units has been based on whether to use the centimetre or the millimetre. Although going from the millimetre to the metre is a large jump, keeping only factors of 1000 helps locate the decimal point. The biggest objection to the mm occurs when raising it to powers. Moments of inertia for sections are given in mm^4 in Britain, with the next usable unit being m^4 which is 10^{12} times as big. As one British Engineer puts it: "It's nothing for 10^{14} to appear in a number. With the old imperial system numbers...were nearer to one...we have moments of inertia in either m^4 or mm^4...You can't use centimeters." (B,2,3)

Even more heated debate is found in the units for force. As mentioned before the SI unit for force is the

newton and it is a coherent unit, which means that it is obtained by multiplying one unit of mass (kg) by one unit of acceleration (m/s^2). Units of force used in the imperial system and in early versions of the metric system are gravitational units, which means that a unit of force is obtained by multiplying one unit of mass (lb. or kg) by g units of acceleration (where g is gravitational acceleration). The gravitational force units so obtained (pound-force, lbf and kilogram-force, kgf) have the advantage that their magnitude is equal to that of their counterpart masses in the earth's gravitational field. As one author claims, these units lead to "considerable savings in commercial-technical interaction... and in design calculations" (B, 1, 138).

Proponents of the coherent unit point out that g varies slightly over the earth's surface and is completely different on the moon. South Africa goes so far as to differentiate between masspieces (calibrated in kg) and weightpieces (calibrated in N). Weightpieces are good only in the area near where they are calibrated because g is different and therefore the force (weight) of the piece is different elsewhere (B, 1, 160). Detractors of the newton are quick to point out that g varies by only 0.5% on the earth's surface, which, for engineering purposes is not significant. And, as a British engineer puts it: "...the chances of our carrying out a heavy civil engineering contract on the moon are pretty negative at the moment..."

The newton's supporters do, however, have one powerful overriding argument. The use of electrical units such as the watt and the volt are widespread and unquestioned, but they are based on the newton (the watt is a newton-metre/second and the volt is a newton-metre/ampere-second). In dynamics, using absolute units allows one to insert g if and only if it is involved in the problem, whereas with gravitational units, g is inserted when it is not a factor and omitted when it is a factor. The advantage to absolute units in dynamics is also unquestioned. The use of the newton in other fields, then, will allow for more useful interdisciplinary communication.

Many units for stress have been proposed and discussed. The arguments for and against using the kilogram force per square centimetre are the same as those given in the previous paragraph. There is some argument, though, about pros and cons of two stress units based on the newton. One is the pascal and the other is the bar. The pascal (a name only recently approved) is equal to a newton per square metre. The bar is equal to 10^5 pascals and is considered convenient because it differs by only 1% from one standard atmosphere, by only 2% from the kgf/cm^2. Also, this convention allows use of the hectobar which is of the same order of magnitude as the tonf/in^2 (1 hbar = 1.38 tonf/in^2). Objections to the bar are that it is not an SI unit and that the hectobar uses a non-preferred prefix. One author objects to the justification of the formulation of the bar as a unit: "It seems that earlier a need had been felt to find new units that had similar values to those with which we were familiar...The bar and then the hectobar accumulated a good deal of support...there is now more support for authentic units and multiples" (B, 1, 75). South Africa, being SI "purists", are converting all work to pascals. In Britain and Australia, the bar is reserved for use only in meteorology. In Australia, the pascal is used for other purposes. Britain uses the newton per square millimetre (10^6 pascals), probably because their decision was made before the acceptance of the name pascal. Indications are, however, that Britain will convert from the N/mm^2 to the megapascal.

There is one more unit controversy of a more subdued nature. Since drivers will not be able to visualize speed limits in metres per second, no one objects to using the non-SI kilometre per hour on the highway. If some countries then base horizontal alignment on a design speed in kilometres per hour, this practice would introduce a conversion factor (km/h to m/s) of the type that using the SI is supposed to eliminate. Some authors feel that when designing geometric elements, they should be based on a design speed in m/s (B, 1, 38).

3.2.2 Units and Rules for Use in Construction

Nearly all the material we have on this topic has come from England; so, unless otherwise stated the practices described herein are British. For the most part, Britain has chosen to follow all the SI rules and recommendations with a few minor exceptions which are continually being discussed. The exceptions are in using the non-SI units of the litre, the hectare, degrees, minutes and seconds for angles, and the hour. Discussion also persists on whether to reject non-preferred multiples such as centi (particularly in connection with linear measurement) and a non-preferred derived unit, the newton per square millimetre.

On the construction site debate between the centimetre and millimetre is still going on. Most of literature we have seen indicates a strong sentiment for using the centimetre. As one author puts it: "...the operative should be able to measure the basic unit used for construction with a rule or a tape and he should be able to visualise this unit of all site measurements. The millimeter...is too small for this purpose" (B, 1, 155). Even members of the academic world have spoken out against sole use of the millimetre: "a member of the construction industry...(asked) whether the decimetre should be used, and...an academic professor...said, 'the centimetre and the decimetre were definitely necessary and should be used'" (B, 2, 2). Despite the criticisms, it must be pointed out that the British construction industry has chosen to use only metres and millimetres for their linear measurements. This policy led many Britons to believe that the centimetre was to be abolished in all sectors of the economy. This is not true. Only the engineering and scientific fields are adopting this policy.

An extension of this controversy is in volumetric measurement. The mm^3 is much too small for volumes and there is general agreement on this fact. In many cases, however, the m^3 is too large and hard to visualize. Therefore, the literature indicates widespread support for the use of the litre on the construction site.

The hour continues in use for labor time and there are

no indications of change.

The last point to be made about the construction site is that pile driving in Britain has not been metricated. Pile driving is still measured in blows per inch and not in blows per metre or millimetre (B, 2, 12).

In surveying, the non-SI practices include using degrees, minutes and seconds rather than radians for angles, and using hectares for areas. The literature indicates that no country is using or plans on using radians for angular measurement. Some discussion has been generated, however, over whether countries using the 360° circle should switch to the 400° (as used in Europe). Some feel that the 400° circle makes computations easier, but there appears to be no sentiment for change. (B, 2, 12).

The jump from m^2 to km^2 is too large for real estate purposes. Therefore, the hectare (10,000 m^2 or 0.01 km^2) is used when describing the area measurements of most surveys. This also applies to right-of-way acquisition.

British suppliers are selling material which is sold by weight in tonnes and kilograms. The tonne, not a true SI unit, is the same as a megagram. Material sold by volume is being priced by the cubic metre. (B, 1, 91).

Manufacturers of large earthmoving equipment are quoting capacities in cubic metres, but for smaller volume equipment, such as concrete mixers, litres are used.

The area of testing is more scientific and exacting and therefore there is a more strict adherence to the SI. Our information on this topic comes from the Road Research Laboratory in England. There, the use of the litre is discouraged as its old definition makes it equal to 1.000028 dm^3 and its new definition equates it to 1 dm^3 exactly. Confusion of the two definitions could cause small but significant errors. The use of the tonne (1000 kg) is also discouraged as its symbol ('t') could cause confusion with the imperial ton. The Road Research Laboratory early

established the practice of encouraging the bar as a unit for stress. Later information indicates, however, that the bar is being replaced by the newton per square millimetre (B, 2, 11). Other non-SI units permitted are the poise, stoke, micron and degree Celsius. The term degree Centigrade is deprecated. Although other sectors (such as surveying) use the are (100 m^2) and the hectare (100 are or 10,000 m^2), the Road Research Laboratory has established the policy of avoiding these units when possible (B, 1, 110). The laboratory also permits the use of the centimetre where appropriate.

3.2.3 Units and Rules for Use in Operations

The unit used for posting speed limits will undoubtedly be the non-SI kilometre per hour. Motorists would find it difficult, if not impossible to relate to the SI unit, metres per second. Distances, then, will obviously be posted in kilometres.

In the area of maintenance, the British Standards Institute provides the following list of units (B, 1, 56).

Quantity	Existing Unit	Metric Unit
Rate of coverage (binder)	square yard per gallon	liter per sq. metre (l/m^2) *
Rate of coverage (chippings or mixed material)	square yard per ton	kilogram per sq. metre (kg/m^2) *
Rates of grass seeding, gritting and salting	ounce per square yard	gram per sq. metre (g/m^2)

* Reciprocal conversion

Note that the first two units have reciprocal conversions. The new units are more consistent with the designation of rate of coverage.

3.3 Metrication Methods

In Great Britain, the approach to metrication has been to convert voluntarily with the government providing incentives by purchasing metric materials and building metric projects. This approach has worked for the most part, although the program did lose some momentum due to an unfavorable political situation in 1972 and 1973 (B, 1, 54). To coordinate activities, the British Metrication Board (BMB) was established in 1969, four years after the beginning of the metrication program. Looking back, most feel that the BMB should have been established earlier. Another coordinating body is the British Standards Institution (BSI). Since industry's request was the motivation for metrication in Britain, the BSI, being a representative of industry, has been a leader in the program.

Although industry motivated and led the way to the metric system, it was thought that the public would follow (B, 1, 110). However, Britain also decimalized their currency in 1971 and the public had an unfavorable reaction to it because quite a few associate decimalization with inflation. Since many people unconciously associate metrication to decimalization, public agencies are forbidden, for political reasons, to carry out any metrication activity which impinges directly on the public (B, 2, 1).

The coordination done by the BSI consisted of gathering thousands of individual metrication timetables and producing a coherent, coordinated program from them (B, 1, 47). In addition the BSI set up lectures on metrication. As a rule, these lectures were attended by many surveyors, architects and contractors, but by very few engineers and manufacturers (B, 1, 126).

Two recurrent themes are found in the information gathered from Britain. First, dual dimensioning should be avoided whenever possible. The reason for avoiding dual dimensioning is that it is a waste of time. If both dimensions are there, people will only look at the imperial and never learn the metric system.

The second theme concerns rationalization, i.e. the process of choosing a "rational" metric size for a product instead of converting its imperial dimension exactly to metric. For example, a pipe with a 6 inch diameter could be "soft" converted to 152.4 millimetres. "Soft" implies that the conversion only takes place on paper and the object remains unchanged. But for rationalization it would be necessary to "hard" convert the 6 inches to 150 millimetres.

The consensus is that rationalization is necessary, as otherwise some very awkward and unwieldy numbers would result. However, there is some disagreement on whether "rational" conversion should be only guided by a desire to have convenient numbers. Some claim that the entire logic behind a standard, a specification, etc. should be repeated in metric units in all of its steps, rather than just "rationally" convert the result of the last step. Additional information on this topic is given below.

3.3.1 Design

The first issue to be discussed here is preparation. Metrication is coming, and in order to meet it efficiently, some preparation is required. In Great Britain, the National Building Agency (NBA) designed several pilot projects in SI units. The NBA found that with adequate preparation and an SI familiarization program for the staff, there was no real difficulty in converting (B, 1, 8). In fact, the calculations and dimensioning of drawings went even faster in SI units. The experience should not lead one to think that metrication should be very easy, rather it shows that the facility of conversion depends on the preparation (B, 1, 8). A similar experience is found in the Rover Company, Limited of England. After preparing the design office by issuing all metric instruments and standards, there was little difficulty in converting to the SI (B, 1, 46). Employees found little difficulty in converting back and forth between imperial and metric. Also, surprisingly, dimensional errors were negligible (B, 1, 46).

Once a preparation program is started, the next

problem is producing a plan for the timing of the change. In industry metric designs can be introduced at the same rate as new designs are usually begun (B, 1, 3). But for contract work there is a different philosophy; according to one author, once a design office does its first metric job, it should never have to go back to imperial as all new contracts will be metric (B, 1, 156). In any case, timing becomes academic after a metrication program is well underway because after the metrication of semi-finished materials it becomes expendient to design in metric (B, 1, 51).

There is much discussion in the literature about rationalization. That is, new metric dimensions should not be converted arithmetically from old imperial dimensions ("soft" conversions), but they should be changed to rounded metric values which fit logically with other "rationalized" dimensions (or, "hard" conversions). In order to insure that everyone follows the same procedure for rationalization, the British Standards Institute published a recommendation (BS4318) entitled "Recommendations for Preferred Metric Basic Sizes for Engineering." Rationalization precludes the situation where the design process would continue to use imperial units, and the final answer would be converted to metric units (B, 2, 11).

In order to remove conversion constants and account for rationalization, computer programs used in design have been reworked from scratch (B, 2, 11).

a. <u>Specifications and Standards</u>

One of the most delicate issues about converting specifications and standards is timing. In any conversion program, this should be first priority. Without standards, metric design is impossible; so a holdup in standards can delay the entire program. But it is impossible to convert all standards at once. Standards are interdependent and some must be converted before others. As an example, the British Road and Bridge works standard is based on 180 other British standards, all of which had to be metricated

before metrication began on the Road and Bridge works standard. Obviously, then, the metrication of standards is a tremendous task which will require many years to complete. It may be desirable, however, to do design work in metric units before this long process is finished. Both Britain and New Zealand ameliorated this problem in two ways. First, metric design commenced after only the basic and key standards were converted (B, 1, 158). Any design process requiring unconverted standards was handled by issuing memoranda giving suggested metric values to be used in place of the imperial values given in the old standard (B, 2, 11). For imperial specifications not handled by the memoranda, direct arithmetic conversions were made (B, 2, 3). To aid the designer in finding converted standards and supplemental memoranda, the British Standards Institute published periodically a list of metric standards.

The metrication of specifications and standards not only allows metric design, but encourages it. If plans must legally meet a metric specification, it benefits the designer to do the job in metric in the first place to avoid the arithmetic conversions required to determine the legality of the plan (B, 2, 2).

Although it is generally agreed that metric standards should not be a simple conversion of imperial standards, there was some discussion about the use of direct conversions in an interim period. In Britain, the plan called for no such interim standards. Instead, it was thought that entirely new, rethought metric standards should be used to replace the old standards (B, 1, 15). This plan did not materialize in practice because it took much longer than expected to produce entirely new standards, and designers had to have something metric in their hands before the new standards were complete. Therefore, Britain issued interim specifications with blanks next to all imperial figures; massive memoranda were then issued to fill in the blanks (B, 2, 11).

In New Zealand the same process was followed (i.e., interim specifications followed by completely revised

specifications), but the Standards Association of New Zealand felt that for some standards, a simple arithmetic conversion of the old imperial figures would do as a permanent conversion (B, 1, 158).

Since metrication of standards allows for a revamping of the entire process, the chance to simplify at the same time should not be overlooked. In Britain, the conversion policy was to radically cut back on unneeded variety wherever possible (B, 1, 47). As an example, British imperial standards give three definitions for "Fine Aggregate"; for coated macadam it is aggregate passing the 1/8" seive; for asphalt, it is aggregate passing the No. 7 B.S. seive; and, all concrete aggregate passing the 3/16" seive is known as "Fine Aggregate." (B, 1, 15). During metrication, these three different standards could be reduced to one.

Although it is generally agreed that rationalization during conversion is desirable, there has been much discussion about it. In Britain, the Department of the Environment established a working committee consisting of public employees and representatives from private industry. The committee first converted the Road and Bridge Works specification to metric figures with four decimals by using simple arithmetic conversions of the old imperial figures. Then the committee met to decide how each of these absurdly accurate figures should be rounded and rationalized (B, 2, 1). The process must necessarily be complex and seek out the opinions of many knowledgeable persons because it could have many serious ramifications. For example, it would be undesirable to rationalize a specification in such a way as to require that an entire fleet of earthmovers be scrapped (B, 2, 1). One must rationalize with capital investment in mind. This constraint may cause rationalization inconsistencies. For example, 2¼" could be rationalized to 50 mm in one case and to 45 mm in another (B, 2, 1). For this reason, every imperial figure given in the old specifications must be examined carefully. Finally, the rationalization process must take into account international standards. New metric standards should agree with

international standards wherever possible (B, 1, 50). As one last point, the following process was used by Britain in converting the formulas found in their Road and Bridge Works specification. All values of independent variables used in a formula were rationalized and then put into the new metric formula. The resulting values for the dependent variables were then listed as usual (A, 2, 39).

The rationalization process followed is not without critics. Some have felt that the whole procedure is designed to find a fairly well rounded metric figure that comes close to being the exact equivalent of the old imperial figure. This is not in the spirit of rationalization which calls for the specification to be rethought in metric. For example, the construction module is 300 mm. This, to some, is not a truly rationalized metric figure as 200 mm or 500 mm might be. Instead, the critics counter, this module was thought up because it differs from a foot by only 4.8 mm. The critics claim that one should not hunt for "rounded" metric values that come close to imperial figures; one should "think metric" from the start and forget about what the imperial values were (B, 2, 2).

Another area of concern in metricating specifications is tolerances. Most of our British information suggests that tolerance limits should be rounded so that the new tolerance is looser. This is suggested because tighter tolerances cause greater expense and because old imperial parts may fit the new metric specifications within the looser tolerances (B, 2, 1).

A problem that may arise in issuing revamped specifications is that they may not be correctly interpreted. Britain solved this problem for construction specifications by using the Building Research Station as an arbitrator in the interpretation of the metric standards (B, 1, 50).

In the United States, the process followed by Britain and New Zealand has begun. The American Society for Testing and Materials has now soft converted most of their standards.

b. <u>Drafting and the Drawing Office</u>

Much discussion on this topic has centered around whether or not dual dimensioning is desirable. Some of the literature takes the position that dual dimensioning is not desirable and all metric drawings should contain only metric units (B, 1, 156). The intent is that the imperial dimensions should be forgotten as soon as possible and that confusion due to misreading the units on a drawing must be avoided. Although this intention is undisputed, some British organizations have found practical reasons for requiring some dual dimensioning. For example, the Newall Engineering Company, Limited found that if their drawings contained both imperial and metric dimensions, then parts could be machined on either metric or imperial equipment (B, 1, 46). However, the company dropped dual dimensioning as soon as possible (i.e. as soon as most of the equipment was metric). The interim period lasted approximately three years (B, 1, 46). Buck County engineers found that dual dimensioning was necessary to express the metric dimensions of early converted products on imperial drawings but recommended that the practice be dropped as soon as possible (B, 2, 11).

At least one author suggested a type of dual dimensioning which would hopefully eliminate the confusion caused by the practice and still retain its advantages. The method, used by The John Deere Company in the United States, is to list each metric dimension found on the drawing in the upper left hand corner of the plan. Next to this list is a list of corresponding imperial equivalents for each metric dimension (B, 1, 45).

As for the standard method of dual dimensioning, there is a wealth of literature concerning the intricate rules to follow. The reader is referred to the following references for further information (B, 1, 124-44-64). The main idea is for imperial (metric) dimensions to appear alongside metric (imperial) terms in brackets or parenthesis. The idea is complicated by rules for converting tolerances.

The timing of the metrication of standard drawings is easy. Once the first metric contract comes in, standard drawings should go out only in metric from then on (B, 2, 11). To avoid confusion, all metric drawings then produced should be stamped with an appropriate symbol to indicate that it is metric (B, 2, 12). In the spirit of going metric as quickly as possible, one British firm (the Rover Company, Limited) replaced all their imperial drawing equipment with metric equipment so that draftsmen and designers would "think metric" and not convert from the imperial (B, 1, 46).

At times it is necessary to show an imperial part on a metric drawing or a metric part on an imperial drawing. If a metric product is shown on an imperial drawing the metric dimensions should be given followed by the equivalent imperial dimensions (to the nearest 1/16") in parentheses (B, 1, 85 and B, 1, 90). If an imperial product is shown on a metric drawing the imperial dimensions should be shown followed by the equivalent metric dimensions (to the nearest millimetre) in parentheses (B, 1, 85 and B, 1, 90).

When expressing metric dimensions on a metric drawing, all dimensions in metres should be given to three decimal places, and, all dimensions in millimetres should be shown in whole numbers. If these rules are followed, and there are no ambiguites, the dimensional symbols (m and mm) may be omitted. Otherwise, the dimensional symbols must be used (B, 1, 151 and others).

There has been good agreement in deciding which metric scale ratio to use. Most agree that scale ratios should be in the following form -- $1{:}a\times10^n$, where a = 1, 2 or 5 and n is any integer (B, 1, 64 and others). There have been some difficulties with these scales in Britain, however. Designers used the 1:20 scale for concrete reinforcements and 1:50 for most of the general arrangements drawings. For the larger structures, however, neither of these was satisfactory, so they "went back" to the 1:33 1/3 scale (B, 1, 27).

The last point to cover is that most metric European countries use first angle projection on their drawings, while the United States uses third angle projection. Although this is not truly a metric issue, it is bound to be considered as part of a program of complete change. There is considerable pressure to adopt the third angle projection as an international standard, however; so U.S. firms plan to keep it (B, 1, 64). There is a further discussion about changing standards and specifications in Section 3.5, "Metrication of Standards and Specifications".

c. Geometric Design

The main task reported in the literature under this heading is the revision of the existing manuals for geometric design of urban and rural roads. Consult section 3.3.1 a for additional information. Certain comments about the details of changing design manuals are given here, however.

As was stated in the section on standards, certain standard values which are independent variables in a given equation were converted and rationalized in the metric system. Then, values of dependent variables were computed and listed as usual (A, 2, 39). To illustrate this, here are two sets of design speeds, from the old (imperial) and the new (SI) manual in Great Britain. The latter were found by converting and rationalizing existing design speeds, as shown.

30	mph	became	50	km/h
35	"	"	60	"
40	"	"	65	"
50	"	"	80	"
60	"	"	100	"
70	"	"	120	"

The only significant difference in the table is the difference between 70 mph and 120 km/h (74.5 mph). This caused certain other standards to increase as well, e.g., minimum radius at 120 km/h is 960 m (3150 ft.), while for 70 mph the minimum radius is 2800 ft.

One independent variable used by Britain in computing design standards was not rationalized. The old standard for driver's eye height of 3 ft. 6 in. (1.07 m) was converted to 1.05 m, which is rounded, but not rationalized (B, 1, 154). In New Zealand, however, eye height was rationalized to 1 m, which is shorter than it was previously (B, 1, 139). This decision will increase requirements to meet current sight distance criteria.

There is a firm feeling in the literature that metrication of the highway design process poses no serious problems, but it is "emphatically stressed" that the metrication of design information and of measuring equipment at an early stage is vital (A, 2, 15).

d. Bridge Design

According to the literature, most of the problems that are encountered in the metrication of bridge design, are the inconvenient numbers that result from using the SI units for structural design. The reader is referred to the section on units for additional information. Authors who discuss the inconvenience of the SI offer the following alternatives: an interim inch-pound force-second system using decimalization, or a more loose combination of the SI and the "common" metric (B, 1, 11 and B, 1, 60).

In discussing the process of changeover, the main disagreement is about the convenience in calculating with SI units; there is agreement that the transition itself will not be difficult and there are some reports on how surprisingly easy it was to achieve familiarity with metric units (B, 1, 27).

It must be emphasized, however, that the metrication of the design process cannot proceed without the metrication of specifications and standards. See the section on standards for more information. The practice to combine revision of a standard or specification with its metrication has created a real hardship to engineers in England especially

when the revision introduces new design concepts and procedures e.g. "Load Factor and Limit Design".

3.3.2 Construction

This section begins by defining some of the problems expected and encountered in the construction industry. Possible solutions to some of these problems are discussed in later sections. One British publication identifies the following problems (B, 1, 87): (1) the natural human reaction is to resist change, there is no reason to expect metrication to be an exception; (2) all construction personnel will require retraining; (3) there will be an initial reduction in output due to working with new terminology; (4) new tools and equipment must be obtained; (5) old tools and equipment must be adapted; (6) personnel must relearn prices for new rational metric amounts; (7) reference data and tables will need revision. Another source indicates that old labor personnel may feel threatened by younger employees who know the metric system better (B, 2, 1). For additional review of the problem see section 3.8.

Finally, another source tells us about a problem that the British did not anticipate. It had been originally planned that dimensional coordination (DC) would proceed simultaneously with metrication. However, although metrication proceeded relatively smoothly, DC lagged badly (B, 1, 54).

Unlike design, the construction field has the disadvantage that it cannot make a one time conversion. A construction crew may have to work on a metric project one day followed by an imperial project the next day and another metric project on the third day. According to "the trade union officers concerned...there will be no difficulties on site provided each operator has the appropriate rule for the job" (B, 1, 156).

In order to uncover unanticipated problems, an Australian publication suggests the building of metric pilot projects 6 to 12 months before the national timetable

calls for other projects to be metricated (B, 1, 85).

a. Surveying

The most massive task still facing Great Britain in this area is the metrication of the Ordnance Survey. Before the move to the metric system, there had been an effort, underway for 20 years, to cover the entire country by maps with 1:2500 and 1:1250 scales. To replace these with the corresponding rational metric scales of 1:2000 and 1:1000 would require too much additional labor; so, at least for the foreseeable future, the scales will remain as they are (B, 1, 40). Contours, spot heights and linear distances will be metricated, however, and it was estimated in 1970 that it will take an additional 12 years to have a complete set of metric maps (B, 1, 53).

The six inch to one mile (1:10560) Ordnance Survey maps have been changed to 1:10000 and the contour interval has been changed from 25 ft. to 5 m in flat areas and to 10 m in mountainous areas (B, 1, 40). The first of these metric maps were produced in October, 1969 (B, 1, 40). The one inch to one mile maps (1:63,360) are being replaced (starting in 1974) by 1:50000 metric maps (B, 1, 54). All metric sheets being produced have the note "HEIGHTS IN METERS" (B, 1, 90).

The most troublesome problem faced by the Ordnance Survey is the metrication of contours. The following possibilities have been suggested: (a) Retain the contour interval (CI) and relabel the contours with a metric value; (b) Interpolate new contours; and (c) Survey new contours (B, 1, 16). It was decided that a rational CI was necessary and that (b) was too inaccurate. A resurveying effort is underway.

Benchmarks, spot heights and parcel designations are much easier to metricate. The following accuracies are to be used in England: (a) benchmarks to ± 0.01 m, (b) spot heights to $\pm$ 0.10 m, (c) parcels to $\pm$ 0.001 hectare (B, 1, 40). For the time being, parcel areas will also be given in acres.

In Britain, it is felt that the switch to metric contours will cause little trouble in laying out highways (B, 1, 16). In the field, levelling will be done to ± 5 mm and measurements for cross sections will be made at 20 m intervals (B, 1, 15). Original surveys for highways will be, as before, to a scale of 1:500 (B, 1, 15).

b. Contractors

There are two major problems discussed in the literature on this topic. The first is that contractors may overprice metric jobs to provide a safety factor against judgemental errors. The other is that contractors may take the metric plans, convert them back to imperial units and build the project in imperial. Concerning the latter, one British highway official said, "I will guarantee that the contractors will do that for at least half a decade" (B, 2, 1). The problem of costs is discussed further in the Section 3.9.

Another area of concern is the problems resulting from the lack of imperial or metric materials needed to fulfill the contract. In Britain a special page us used, in each contract, for listing all metric (imperial) materials the contractor proposed to use on an imperial (metric) contract (B, 2, 1). In Australia, the National Public Works Conference and the Master Builders Federation of Australia have written contract clauses to ameliorate this problem (B, 1, 82).

There is some discussion on this topic in reference to quantity surveying (estimating). None of the quantity surveyors techniques should change, but it may take a while to adjust to the new linear unit of measure. The real problem for the quantity surveyor is to be able to establish metric reference points so that the numbers given to him in metric units are meaningful, so that he can tell at a glance about how much something will cost (B, 1, 87).

Despite these problems, most of the information reviewed indicates that contractors will have little trouble in converting. From Britain, after most large civil engineering contractors had experience with the metric contracts, "few difficulties have been met, where there has been adequate planning and preparation" (B, 1, 49). In the United States, polls taken indicate "no great difficulties would be encountered in such a conversion. Most feel the major problems lie in the area of manufacturing" (A, 2, 13).

In addition, however, contractors face the following two problems: "re-equiping with new or recalibrated site machinery and equipment; and coordinating sub-contractors and suppliers who may be slower in their change to metric than general contractors" (B, 1, 87).

c. Materials Suppliers

In general, only minor difficulty is expected of metrication in this area. From Great Britain we are told that "with the possible exception of storage problems where dual stocking is necessary, the difficulties involved...will be no greater than have been experienced with normal commercial and design changes in the past" (B, 1, 49). This statement is somewhat optimistic, however, in view of actual experience.

In order for the conversion to proceed smoothly for suppliers, dual stocks (i.e., stocks of both metric and imperial sizes) should be minimized. To this end, a two to three year conversion period is best (B, 1, 3). However, customers' conversion programs usually run longer; so the suppliers will have to run a sub-optimum conversion program if they are to meet demand.

Without careful coordination, the metrication of materials could be delayed due to the following indecision loop: "those responsible for the design of construction projects refrain from specifying coordinated metric components until they are certain that these are in production and will be available when required on site" (B, 1, 53).

On the other hand, manufacturers are reluctant to embark on metric production until they see an assured market, both adequate and continuous. To resolve this problem the British Standards Institution (BSI), materials suppliers and customers are attempting to keep communications open. The suppliers are producing metric catalogs and the BSI is publishing periodical buyer's guides (B, 1, 3). In order for supplers to meet demand, they emphatically state that estimates of quantities required must reach them from designers early (B, 1, 3). Suppliers must watch the demand very closely in order to avoid excessive stocks (B, 1, 50).

An example of a case where communications between the supplier and the purchaser were lacking is found in British screw supplies. As related by one author, "small stocks of sizes from the first choice in BS4183 had been manufactured but sales were unrewarding -- meanwhile equipment designers complained that the sizes they needed were not available" (B, 1, 46).

For imperial products, it is felt that imperial materials will be made "for maintenance and replacement purposes as long as the demand continues at an economic level" (B, 1, 50).

An entirely different approach which would eliminate many of the problems previously discussed is as follows: Suppliers could manufacture metric products with imperial labels. For example a part measuring 250 mm x 350 mm would carry a label of 9 27/32" x 13 25/32" or 10"x14" nominally. Then, at an appropriate time, the supplier can start producing these products with the metric label. This has been tried in Australia and results indicate no drop in demand due to labels with fractional dimensions; it worked (B, 1, 85).

On the receiving end, purchasers must have a thorough knowledge of the metric system. Without it, a buyer may end up paying more than the worth of the items received (B, 1, 120).

Although most suppliers found it easy to convert their products to metric dimensions, some had problems. In Britain, for example, precast concrete used in construction must pass certain tests before it can be used. The test procedures required are intrinsically bound to imperial units; thus it is difficult to design a metric precast concrete unit (B, 1, 120). Nevertheless, the components of concrete are going metric. Since January, 1971, British firms have sold cement by the 50 kilogram bag or by tonnes in bulk orders (B, 1, 150).

Some problems surfaced in Britain during the changeover of steel products. Our sources indicate that the steel industry converted very quickly -- almost overnight (B, 2, 3). One of the repercussions was that, at least for some highway projects, the plans which called for imperial sections quickly became obsolete because some steel items went metric in the middle of the project. Construction workers on site, then, had to make do with the closest metric equivalents (B, 2, 3).

Special problems concerning small construction firms are also encountered in the literature. These firms have difficulties in dealing with both suppliers and manufacturers of their materials, as their share of demand is not large enough to influence the metrication of manufacturers or dual stocks of suppliers. Similar difficulties were reported in personal communication with some small firms manufacturing construction equipment. In spite of the steel industry's assurances to the contrary, the availability of metric steel sheets, etc. is mentioned as a major problem.

To help solve this problem and the problem of metrication in general, the government, which is the single largest consumer of many industrial products could use its power to influence the suppliers to metricate their products.

d. <u>Testing</u>

In the field of testing, imperial instruments need

replacement and imperial tests need to be recalibrated. The Road Research Laboratory considered recalibration necessary so that all procedures and materials could be converted to rational metric units (B, 1, 110). Before recalibration was complete, only critical dimensions were quoted in metric, and then the quoted dimension was a direct conversion from the imperial.

Much of the controversy about metrication in this area centered around test sieves. The ISO standard suggested sizes which fit very neatly between all the British Standard (BS) sieve sizes. By averaging each adjacent ISO size, the British came up with a series of sieve sizes which nearly match the old BS sieve sizes. An attempt is underway to have the BS proposed series to override the ISO series (B, 1, 15).

Unlike Britain, South Africa has decided to keep existing apparatus and test procedures. Each test will be conducted in the same manner as usual, which consists of a mixture of imperial and metric (though not SI) units. The final answers however, will be converted to SI units (B, 1, 105).

Our latest information tells us that the South African Bureau of Standards is preparing a series of sieve sizes based on ISO recommendations. Imperial sieves will continue to be used after metrication however, because certain test procedures call for it (B, 1, 105). For example, a U.S. 40 sieve will still be used to separate "soil fines".

3.3.3 Operations

According to the literature, metrication of operations would be feasible only under a planned nationally coordinated program. Evolutionary metrication, on the other hand, would cause chaos. Enforcement of traffic laws would be impossible with some areas posting metric signs and others imperial. Maintenance procedures would become ridiculous as it would be nearly impossible to get the right sized

materials and parts all the time (B, 1, 108). There is some disagreement, though, on what form a nationally planned program should take in the area of operations. Some authors feel that dual units would allow the new measuring system to take over gradually and economically (B, 1, 108). Other authors contend that using a dual system of measurement would be the same as using only imperial units; metric equivalents would be ignored (B, 2, 1).

a. Signs

Different countries have pursued different courses of action in this area. This section will relate the experiences of each country studied.

Australia

Australia planned a metric conversion of all road signs during the month of July, 1974. The planners recognized the following two ways to convert existing signs: (1) the sign could be replaced completely; and (2) in some cases, only the numerals would have to be replaced. The second alternative could be accomplished in any of the following three ways: (1) paint out the old numeral and paint on new ones or use and adhesive sticker for the new numerals; (2) take off the old sticker and proceed as in (1); and (3) overlay existing numerals with adhesive metric numerals. The authority to carry out the procedure was to be given to a central section in each state. Each district in the state would appoint a liaison officer to communicate with the central section (B, 1, 77).

The first thing to be done, according to the Australians is to do a field survey of existing signs. The purpose of this is to determine, for each sign requiring conversion, the

"(a) Location...
(b) Type of sign...
(c) Size of sign
(d) Existing legend to be changed
(e) Size and type of lettering
(f) Background material and color

(g) Legend material and cover." (B, 1, 77)

Each type of sign will be replaced. Distance signs will show metres for all distances less than one km (the symbol m will be displayed). For distances greater than one km, distances will be shown in kilometres with the symbol km displayed on the sign for approximately one year (B, 1, 76 and B, 1, 77). Each 5 mile post will be replaced by an 8 kilometre post. Later, the highway will be resurveyed and kilometre posts will be erected for every 2 kilometres (B, 1, 77). Clearance signs will carry dual messages for approximately one year; then the imperial message will be removed (B, 1, 76). Flood depth indicators will be changed from feet to metres. Advisory speed signs will be replaced and will carry the symbol km/h to the nearest 10 km/h. Since speeds were rounded off in the imperial, curves may be resurveyed, instead of converting existing imperial speeds and rounding, in order to avoid excessive round-off errors (B, 1, 77). Load limit signs will show the same number as shown before; the unit indication will be tonne or t in place of ton (B, 1, 77). Temporary construction warning signs, despite a limited life, will also be converted (B, 1, 77).

The most complex task in sign conversion is the conversion of speed limit signs. The new sign in Australia will be rectangular with a white background. In the foreground are black numerals enclosed by a red circle. No units will appear on the sign (B, 1, 76). Motorists will be informed of the change through an intensive media campaign in the two weeks surrounding July 1. The expected speed conversions will change 20, 35, 45 and 55 mph to 40, 60, 80 and 100 km/h, respectively (B, 1, 76). Enforcement is not expected to be a problem. One of our sources quotes Mr. R. H. Bartlett, Chief Engineer of the Royal Automobile Club of Victoria as saying, " The difference between the imperial figure and the metric figure is just too great... No driver worthy of his license would drive at 100 mph in a 100 km/h area " (B, 1, 129).

Rhodesia

Most everyone agrees that speed limit signs should be converted quickly. While Australia planned to do it in one month, Rhodesia did it in one day on April 11, 1972 (B, 1, 88). The new Rhodesian signs are like the Australian signs except that they are round rather than rectangular. While old speed limit signs carried the symbol MPH, the new signs have no unit indication (B, 1, 95).

Canada

Canada plans for a one month conversion in September, 1977 (B, 1, 54). The new speed limit signs should look like the Rhodesian signs. It is thought, however, that both metric and imperial signs should co-exist for a transition period of 3-5 years (B, 1, 107). The purpose of the transition is to accommodate old speedometers and American drivers.

Britain

Because of adverse public opinion, anything in Britain which impacts the general public directly has not been metricated (B, 2, 1). This includes road signs. The conversion of signs was originally planned for 1973, but it was postponed indefinitely. Sign dimension specifications have been changed to metric units, but the tolerances have been increased so that old imperial signs meet the specification (B, 2, 1). At least two plans for conversion of speed limit signs have been discussed. The first plan is to replace existing signs with metric signs covered by an imperial plate. In a two-week period, all imperial plates will be removed. Surveys show that the plan is feasible (B, 2, 1). The other plan is to change each type of road separately so that in a short period all motorways will be converted; then all main A-roads will be converted, etc. (B, 2, 2). The plan for metricating distance signs is to replace imperial signs with metric ones as they wear out. It is not considered important that all distance signs be in the same units (B, 2, 1).

United States

In this country, metric speed limit signs have been erected underneath imperial signs in Huntsville, Alabama (B, 1, 116). The arrangement has a similar appearance to the proposed Canadian signs for the period prior to speedometer conversion (B, 1, 107). While other countries talk of quick conversion of speed limit signs, due to limited traffic engineering budgets, the conversion time in this country may take as long as 5 years. For information on metric road signs posted in Ohio, as part of the Ohio 5-phase Metrication Program, see Chapter 4 of Task 2 which contains a detailed report on that program.

South Africa

Both speed limit and distance signs were changed gradually in this country (B, 1, 54). This is contrary to the philosophy of all other countries studied. It is not known whether any problems were created by this conversion method.

b. Traffic Control Devices (TCDs)

The information we have gathered on this topic consists of the British experience with the metrication of traffic lights (B, 2, 1). The first step in the process was to change the Department of the Environment's (DOE) specification for TCDs. The DOE did not rationalize the specification because radical changes in size would require retooling, which was considered unnecessary. In order to keep costs to a minimum, only new installations need to be metric; a rider on the specification protects existing devices. Since the specification was not rationalized, the change will go unnoticed by drivers. Maintenance is not a concern of the highway department as that is handled by the manufacturer.

3.4 Conversion Timetables

In many of the government publications we have reviewed there appear national timetables for the metrication of certain sectors of the economy. Each of these tables which are relevant to Highway Metrication are reproduced here. After each table there follow two items: (1) the information we have gathered which illustrates how closely the country has followed the given schedule in the highway related areas and (2) Supplemental information about the table and about known highway related details which the table does not cover. Most sections in this review are organized under the following sub-headings: General, Design, Construction and Operation. Since there is much overlap between charts on the four areas, this chapter is divided by giving a sub-section for each country. All tables are located at the end of the section.

All tables, except when otherwise noted, have the following key:

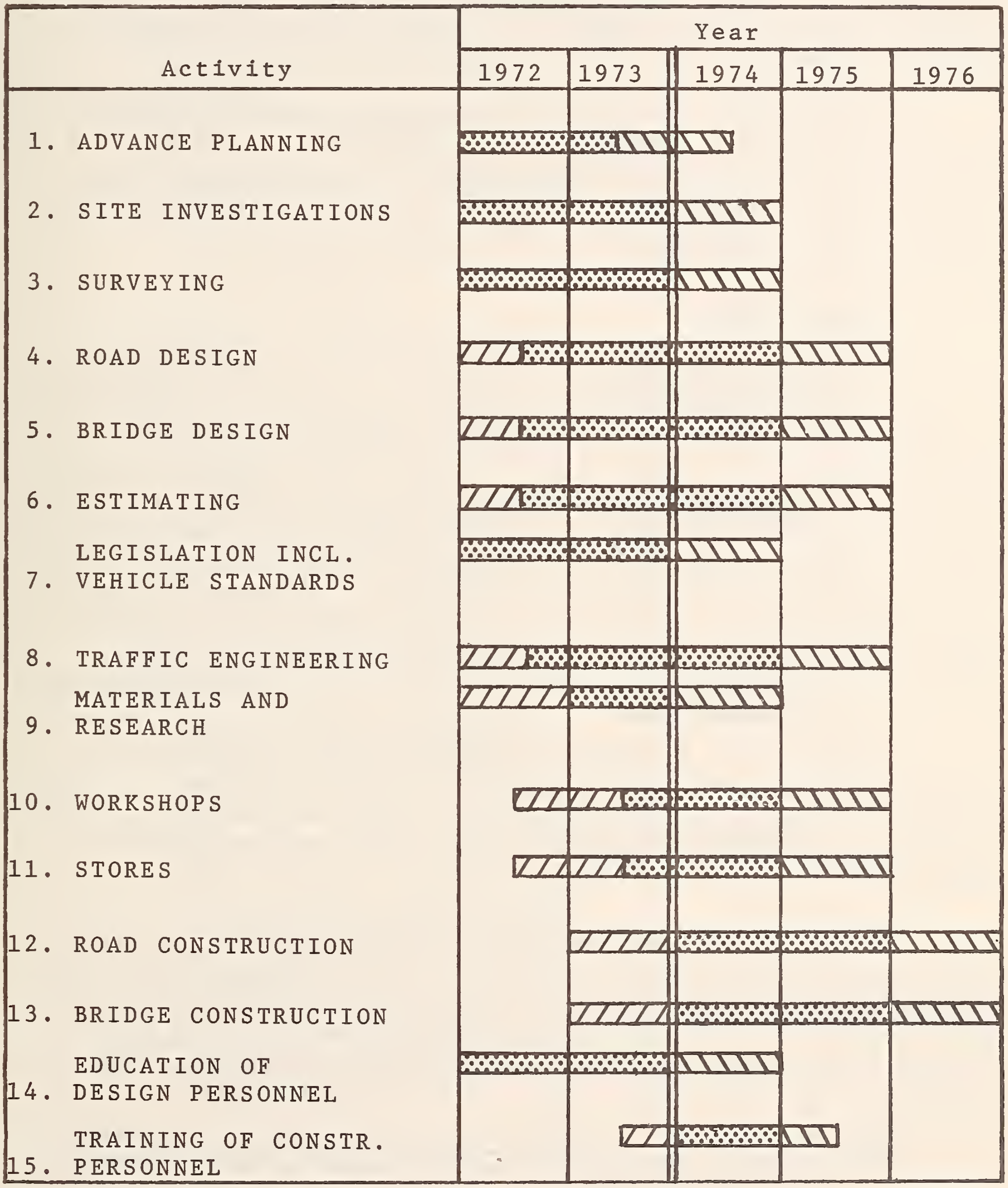
Buildup of metrication activity.
Period of intense metrication activity.
Period during which residual changes will occur.

3.4.1 Australia

a. The National Association of Australian Road Authorities (NAASRA) recommended timetable for metric conversion in the Road Construction Industry is reproduced in Table 1 (B, 1, 85). Only scanty information is available as to how closely this program is being followed. The Land Titles offices of each state are on schedule and by early 1974, no new plans were to be accepted in imperial units in any state. Under materials: cement, lime, concrete, sand and aggregate were all converted on schedule (July 1973). This table is an amplification of the timetable for the Australian construction industry.

b. The metric conversion timetable for the Australian

Table 1. National Association of Australian Road Authorities (NAASRA) Recommended Timetable For Metric Conversion in the Road Construction Industry.



construction industry is reproduced in Table 2 (B, 1, 85). This plan was drawn up because it is important for a metrication plan to be systematic. Random conversion in some areas would cause confusion in others. As yet there is no information available indicating how closely the plan is being followed.

c. The metric conversion timetable for Australian land and surveying activities is reproduced in Table 3 (B, 1, 134). No further explanation of this program was found in the literature. It is not known how closely the timetable was followed.

3.4.2 <u>Great Britain</u>

a. The program for the change to the metric system in the construction industry in Great Britain is reproduced in Table 4. Items 1, 2 and 3 in this table are for publications. The first two of these items refer to very general publications applying to the entire construction industry. The more specific publications are discussed in item 3. These include road and bridge specifications. It was considered necessary to complete the metrication of these publications by January 1, 1969 since that was the date for letting all new contracts in metric and the publications would be necessary to execute those contracts.

Items 4 thru 6 refer to dimensionally coordinated products, which, except for pipes are not relevant to highway construction. Basic materials, such as cement, reinforcement, aggregate, paint and sand are included in item 9.

To conform to the January 1, 1969 date for all new contracts to be in metric terms, it was necessary to begin supplying survey and drawing office equipment by 1968, as shown by item 8. Interim solutions might have included overlays and metric strips, as long as legal provisions were met.

The schedule for item 9 could be met only if metric

Table 2. Metric Conversion Timetable for the Australian Construction Industry.

	1971	1972	1973	1974	1975
1. TIME TAKEN TO PRODUCE PROGRAM AND GUIDELINES					
2. PREPARATORY STUDIES					
2:1 Decision regarding basic metric preferred sizes					
2:2 Key dimensional recommendations based on user studies					
3. ESSENTIAL REFERENCE PUBLICATIONS					
3:1 Time to produce essential reference material of an official nature					
3:2 Time to produce essential ref. mat. of an industrial nature					
4. PRODUCTS WHICH REQUIRE COORDINATED PREFERRED SIZES.					
4:1 Time req'd. for manufacturers to provide tech. info. in metric terms for their products					
4:2 Time req'd for Standards Assoc. to produce metric dimensional recommendations and standards for these products					
4:3 Change to full production of metric coordinated preferred product sizes					

Note: Table continued on following page.

Table 2. (Continued). Metric Conversion Timetable for the Australian Construction Industry.

	1971	1972	1973	1974	1975	1976
5. PRODUCTS WHICH ONLY REQUIRE SENSIBLE METRIC SIZES AND VALUES						
5:1 Time required for manufacturers to provide tech. info. in metric terms for these products						
5:2 Time required for Standards Assoc. to produce metric standards for these products						
5:3 Time req'd.for manufacturers to change to full metric production of these products						
6. PRODUCTION OF METRIC MEASURING INSTRUMENTS AND EQUIPMENT						
7. EDUCATION OF PROFESSIONAL AND TECHNICAL PERSONNEL						
8. CHANGE TO METRIC DESIGN AND DOCUMENTATION ON NEW PROJECTS						
9. TRAINING OF CONSTRUCTION PERSONNEL						
10. CHANGE TO METRIC CONSTRUCTION ON NEW PROJECTS						

Table 3. Recommended Metric Conversion Program for Land & Surveying (Australia).

	1971	1972	1973	1974
1. PLANNING:				
Consideration of preferred units and Scales				
Ammendment of legislation, regulations, ordinances, etc.				
2. PREPARATION:				
Acquisition of Metric Equipment				
Installation of Metric Standard Survey Bases				
Teaching in Surveying and Comparable Courses				
3. IMPLEMENTATION:				
Change from using imperial units to metric units in the following activities:				
Geodetic Surveys	COMPLETED			
Engineering Surveys				
Preparation of Engineering Survey Plans				
Mining Surveys				
Boundary Surveys				
New Cadastral Mapping				
New Topographic Mapping				
Preparation of real property Survey plans				
Lodgement of real property Survey plans				
Issue of new title deeds				
Planning Schemes and orders				
Other Local Government Activities (Related to Land and Surveying)				
General Records				
Real Estate Activities				
Hydrographic and Bathymetric Surveying	COMPLETED			
Valuing				

Note: Table continued on following page.

Table 3. (Continued). Recommended Metric Conversion Program for Land & Survey (Australia).

	1971	1972	1973	1974
3. IMPLEMENTATION (Cont'd.): Conversion where necessary of dimensions on existing maps, plans & records:				
Cadastral Maps				
Topographic Maps				
Plans				
Title Deeds				
Valuation rolls and associated records				
Hydrographic and Bathymetric Charts				
Records req'd. for day-to-day use				

Period of low intensity activity continuing for some years until completion.

information was supplied according to part (a) in items 4, 5, 6 and 7. Some items on the metric contracts could have been rationally dimensioned in the metric system while others were simply converted from imperial. It was not recommended that old contracts be converted before completion.

Item 10 is self-explanatory.

There is a wealth of information concerning how closely the timetable is being followed. Items 1 and 2(a) were met completely and on time. There is no information as to the status of item 2(b). Item 3(a) was not met on schedule. In the road construction industry, there was no road and bridge works specification based on metric units until March, 1971.

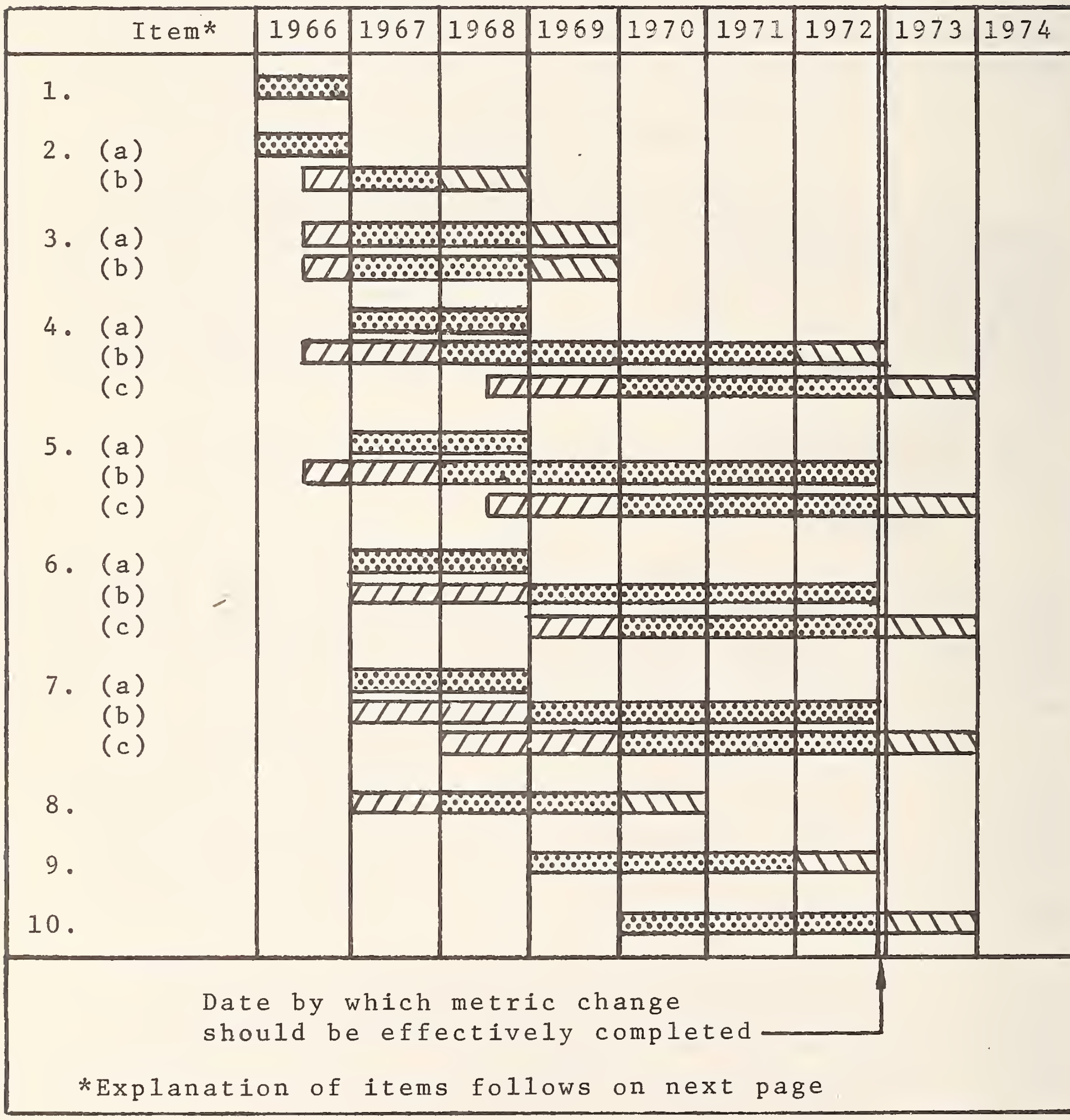
Items 3(b) and 4 thru 6 are not relevant to the topic.

Item 7(b) was behind schedule, but most of the standards were to be ready at the end of 1973. Consequently item 7(c) is somewhat behind, but 1974 saw most basic products available in metric units (B, 2, 2).

Since the road and bridge specification was not available until March, 1971, item 9, the road construction industry, started out 2½ years late. Metric construction commenced quickly, however, and by mid-1974, nearly all new highway construction was metric, 1½ years later than planned by item 10 (B, 2, 2).

b. The schedule for the adoption of the metric system in British engineering is reproduced in Table 5 Information from England indicates that the engineering sector is lagging somewhat behind the program. The latest available figures indicate that by the end of 1975, the engineering sector will have converted only 45% of their production to the metric system (B, 2, 2). It was planned to be 75% complete by the end of 1975 (the termination of the solid bar on the chart indicates 75% completion).

Table 4. Program for the Change to the Metric System in the Construction Industry (Britain).



Explanation of items in Table 4.

1. Time taken to produce the program.

2. Preparatory studies:
   (a) Time taken for BSI (British Standards Institute) to produce its construction industry guide for the use of the metric system.
   (b) Time required for BSI to produce key dimensional recommendations based on user studies.

3. Essential reference publications:
   (a) Time required to make available in metric terms essential reference publications of an <u>official</u> nature.
   (b) Time required to make available in metric terms essential reference publications of an <u>industrial</u> nature.

4. Products for which dimensional co-ordination is essential:
   (a) Time required for manufacturers to provide technical information in metric terms for their products <u>as they are now produced</u>.
   (b) Time required for BSI to produce metric dimensional recommendations and British Standards for these products.
   (c) Time required for manufacturers to change to full production of new metric dimensionally-co-ordinated products.

5. Products which are dimensionally related to those in Item 4.
   (a) Same as 4a.
   (b) Same as 4b.
   (c) Same as 4c.

6. Products which are not dimensionally related to those in Item 4.
   (a) Same as 4a.
   (b) Same as 4b.
   (c) Same as 4c.

Explanation of items in Table 4 (Continued).

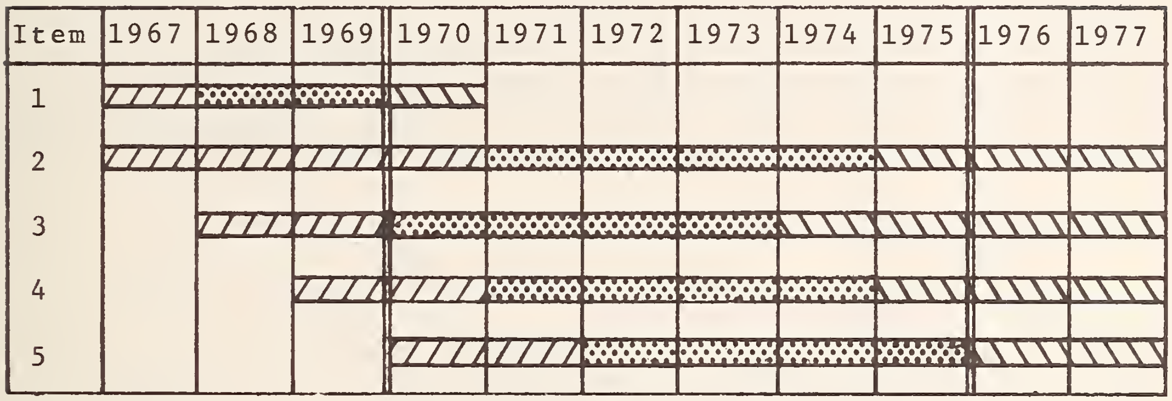
7. Products which are only required to have sensible metric sizes and values.
   (a) Same as 4a.
   (b) Time required for BSI to produce metric standards for these products.
   (c) Time required for manufacturers to change to full production of their products to the new metric standards.

8. Time required to produce all measuring instruments for the construction industry calibrated in metric terms.

9. Time required for designers and quantity surveyors to change to the production of drawings and documents in metric terms <u>for all new contracts</u>.

10. Time required for main contractors and sub-contractors to change to construction based on metric drawings and documents produced under Item 9.

Table 5. The Adoption of the Metric System in Engineering: Basic Program (Britain).



Explanation of items in Table 5.

1. BSI Work: preparation of priority British Standards for metric materials, tools and components.

2. Availability of metric materials, tools and components from stock.

3. Design and Development.

4. Production Planning.

5. Overall period of change to metric production.

c. In addition to the above charts, there is a timetable for the road engineering industry. This table was not found, but it is known that the chart was designed to follow the program for the construction industry. It was expected that all designs submitted after January 1, 1969 would be in metric units (B, 1, 109). As mentioned previously, metric specifications were not printed until March of 1971, so the schedule was not met (B, 2, 2).

3.4.3 South Africa

The metrication timetable for the road construction industry in South Africa is reproduced in Table 6. In addition to those given in the table, the following dates were given: January, 1970 -- surveys to start in metric units. April, 1971 -- metric sizes of basic metal materials and timber to be standard (B, 1, 105).

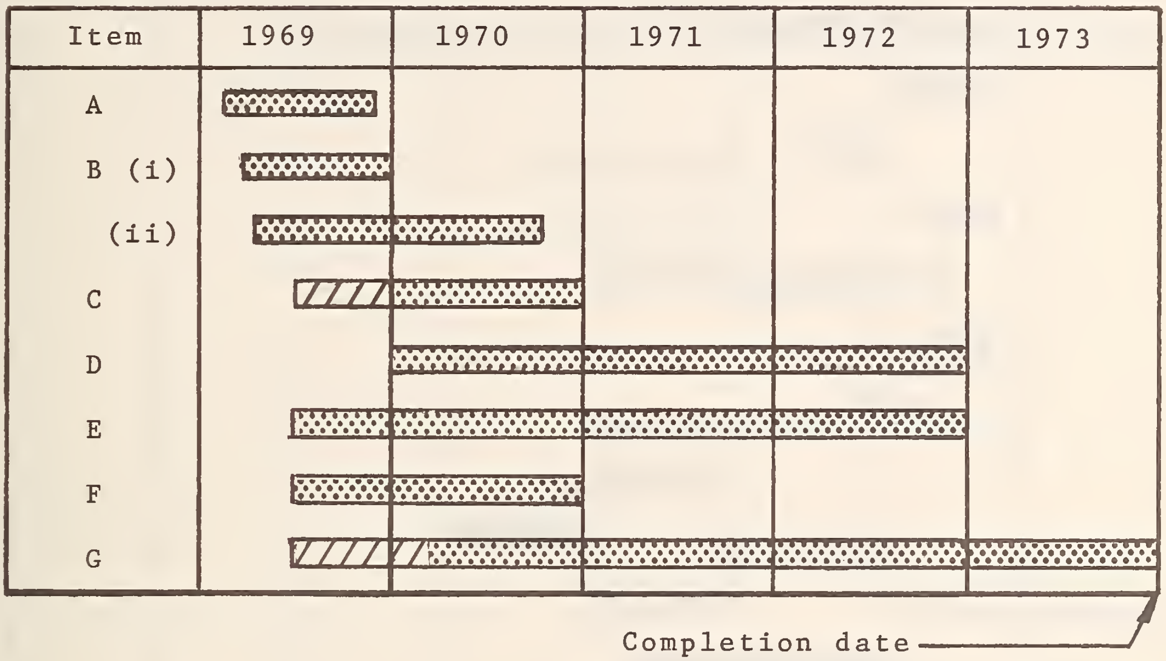
Information on South Africa's success with this program comes from the British Metrication Board's 1972 progress report which states that, for South Africa, "...virtually all operations of government departments were metric" (B, 1, 51). From this it is safe to assume that the program has been followed.

3.4.4 New Zealand

a. The recommended timetable for the application of the metric system to the building and construction industry in New Zealand is reproduced in Table 7 (B, 1, 158). It should be noted that the key given on the first page of section 3.4 does not apply to either of the New Zealand tables. Also note that the abbreviation "SANZ" means the Standard Association of New Zealand. The literature we have reviewed indicates that the timetable is being followed.

b. The recommended timetable for the application of the metric system to road transport in New Zealand is reproduced in Table 8 (B, 1, 17). The information we have gathered to date indicates adherence to the schedule.

Table 6. Road Construction Industry - Metrication Timetable (South Africa).



Explanation of items in Table 6.

A. Decision re scales and units

B. Production of Basic Metric design data
(i) Geometrics and Surveys
(ii) Materials and Structures

C. Change to metric road design

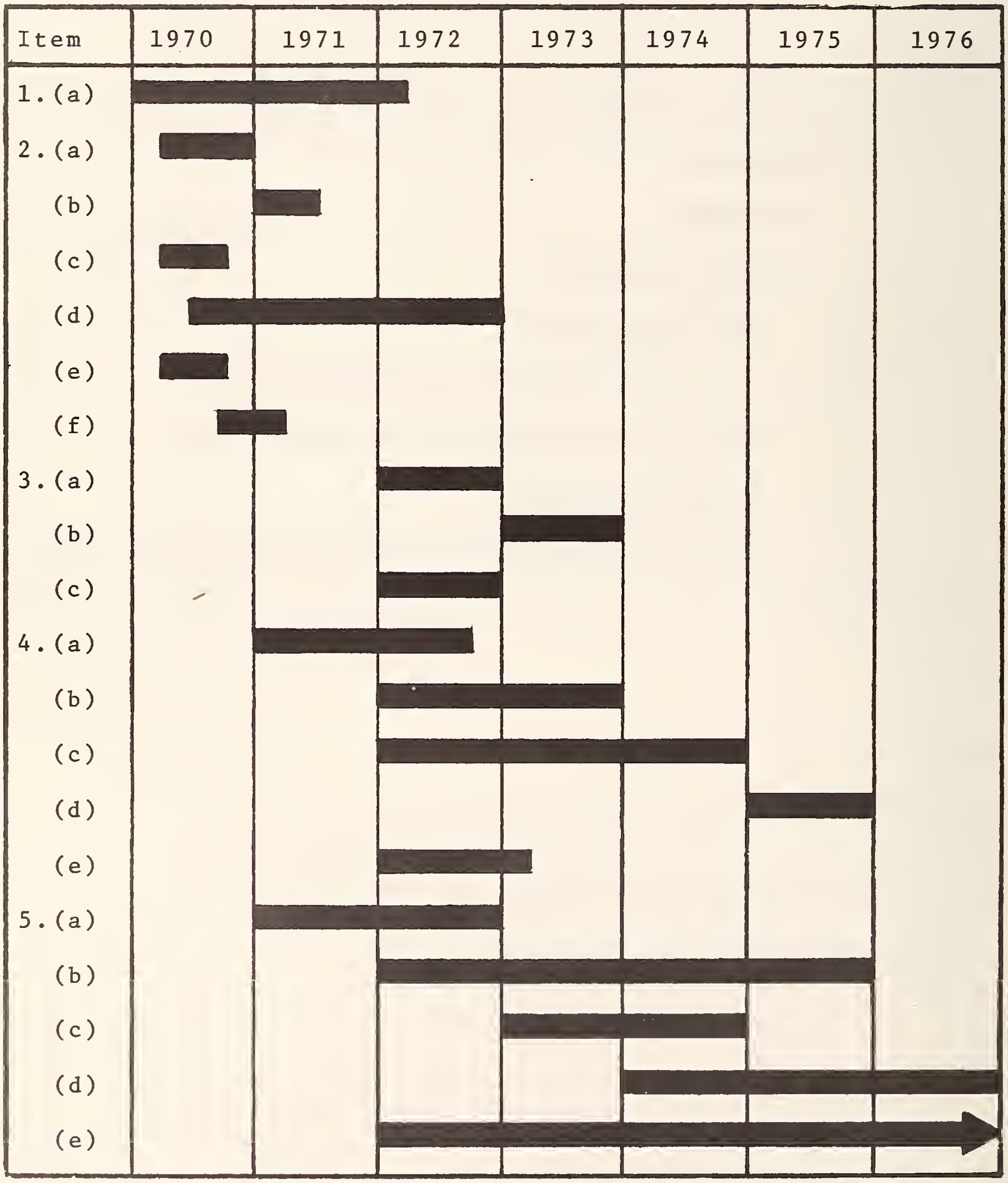
D. Change to metric tenders

E. Acquisition of metric instruments and equipment

F. Training of artisans

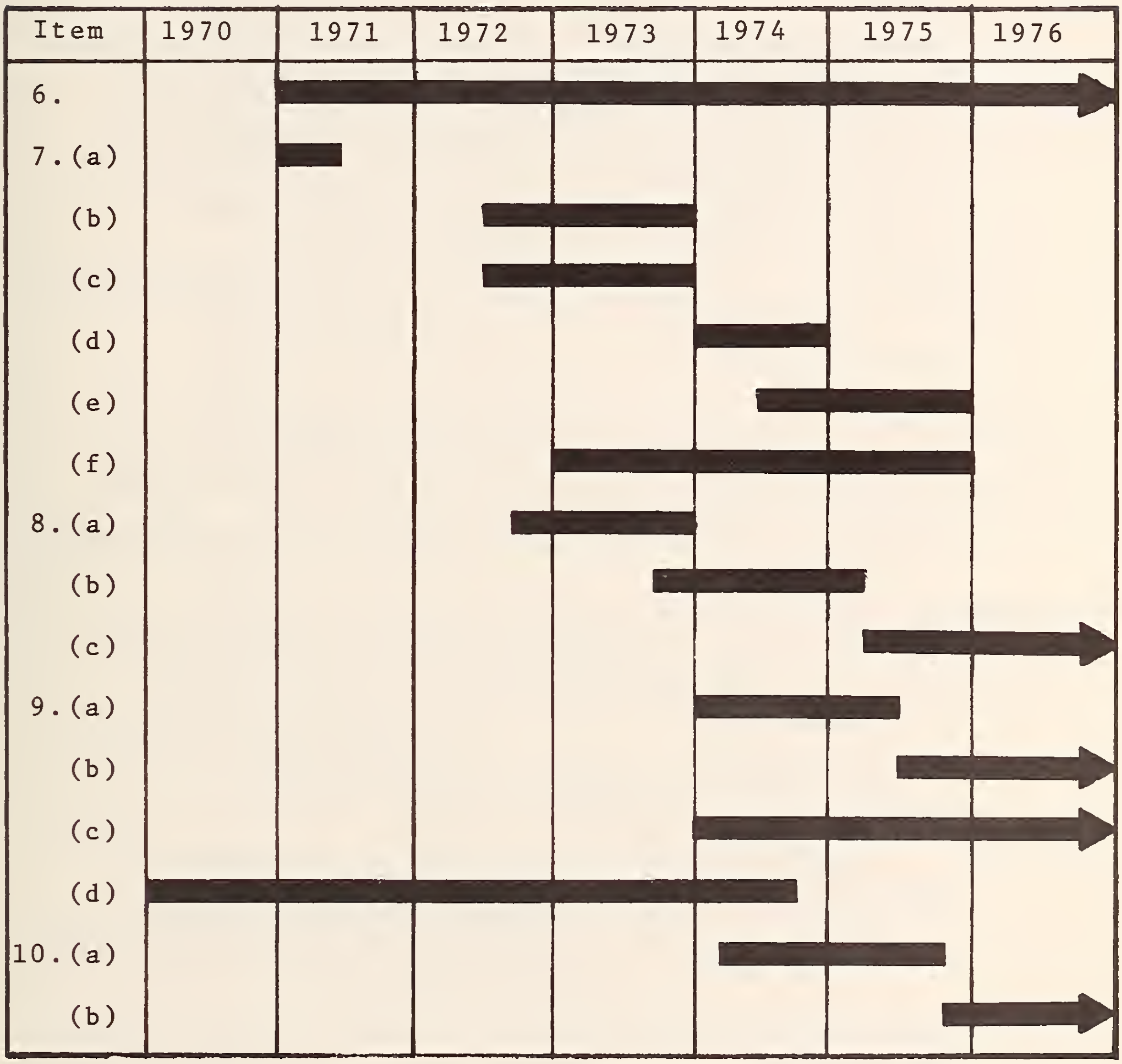
G. Change to metric construction of roads

Table 7. Recommended Timetable for the Application of the Metric System to the Building and Construction Industry (New Zealand).



Note: Table continued on following page.

Table 7. (Continued). Recommended Timetable for the Application of the Metric System to the Building and Construction Industry (New Zealand).



Note: For explanation of items in Table 7 see following page.

Explanation of items in Table 7.

1. Program.
   (a) Period to draft program.

2. Preparatory studies.
   (a) Make draft recommendations for dimensional coordination.
   (b) Make final recommendations for dimensional coordination.
   (c) Draft provisional priorities and requirements for revision of standards by SANZ.
   (d) Draft final for (c).
   (e) Draft provisional priorities and requirements for revision of statutory regulations.
   (f) Draft final for (e).

3. Essential Reference Publications (ERP's).
   (a) Time to produce ERP's of an official nature.
   (b) Period for local authorities to adopt SANZ metric handbooks.
   (c) Time to make available ERP's of an industrial nature.

4. Products for which modular dimensional coordination (DC) is required.
   (a) Dimensioning of products with DC by manufacturers.
   (b) Production of metric standards (provisional) by SANZ for products in (a).
   (c) Planning period for change to full production of metric products with DC.
   (d) Implementation of plan worked out in (c).
   (e) Time required for manufacturers to supply metric technical information for products made in (d) and for products made now.

5. Products which only require sensible metric sizes and values.
   (a) Metric dimensioning of products by manufacturers.
   (b) Production of provisional metric standards by SANZ for products in (a).
   (c) Planning period for change to full production of products that have a change in dimensions.
   (d) Implementation of plan worked out in (c).
   (e) Same as 4(c).

Explanation of items in Table 7 (Continued).

6. Period during which metric measuring instruments are available.

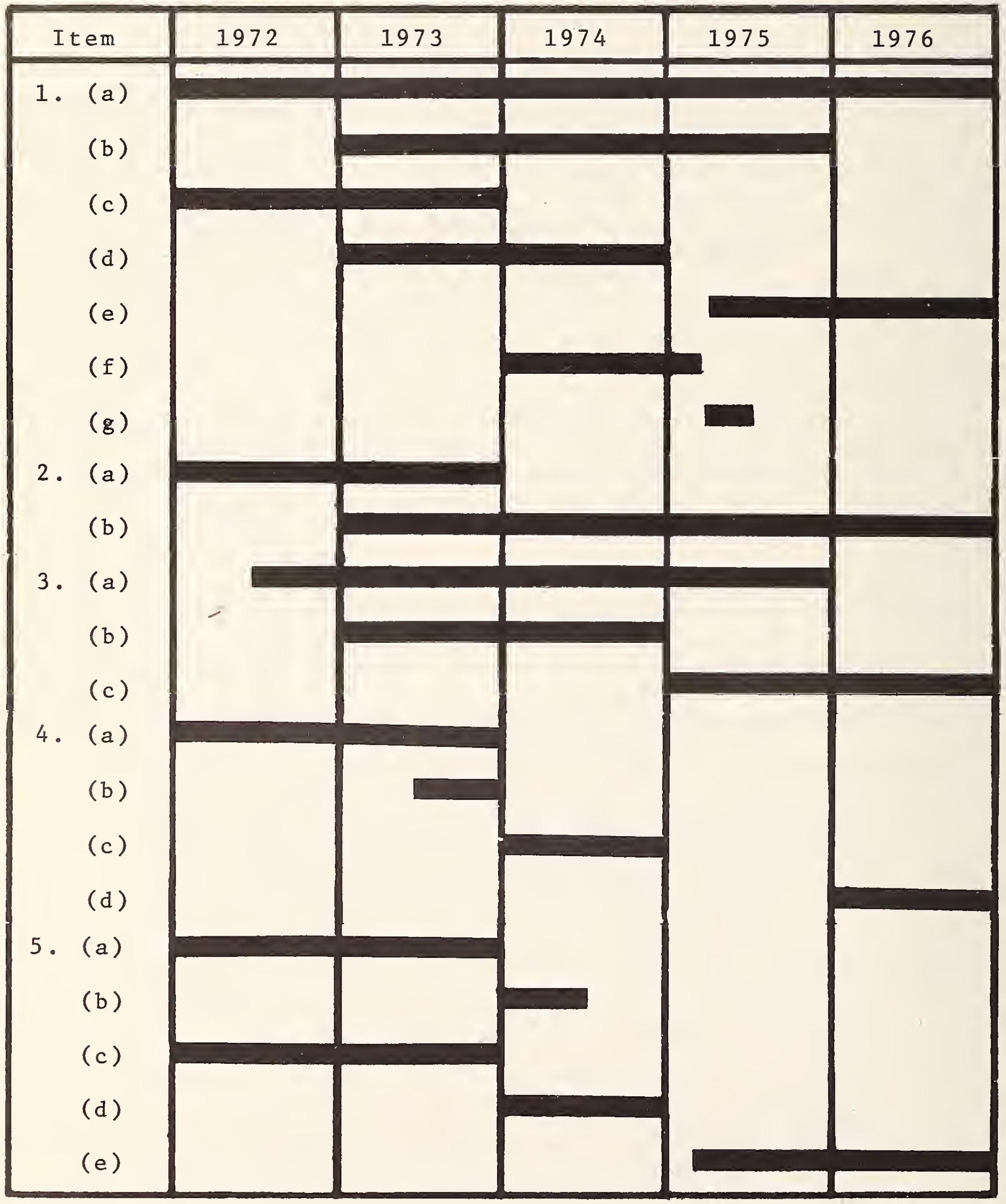
7. Personnel retraining period.
   (a) Statement of course requirements to education sector.
   (b) Training of professional designers, technicians and draftsmen.
   (c) Training of quantity surveyors.
   (d) Training of construction supervisors and foremen.
   (e) Training of tradesmen.
   (f) Change to metric in apprentices' training courses.

8. Metrication of design activities.
   (a) Metric design of selected projects (construction period 2-3 years in the future).
   (b) Metric design of selected projects (construction period 1-2 years in the future).
   (c) Metric design adopted for all projects.

9. Metrication of tendering and permit applications.
   (a) Metric tenders for selected projects.
   (b) Metric tenders for all projects.
   (c) Acceptance of metric support data for permit applications.
   (d) Acceptance of imperial support data for permit applications.

10. Metrication of construction activities.
   (a) Construction work in metric terms for selected projects.
   (b) Construction work in metric terms for all projects.

Table 8. Recommended Timetable for the Application of the Metric System to Road Transport (New Zealand).



Explanation of items in Table 8.

1. Traffic Signs
   (a) New signs to show metric distances (km or m).
   (b) Existing sign converted to metric (km or m).
   (c) Survey of curves with advisory speed signs.
   (d) Erection of "km/h" signs above "m.p.h." on advisory speed signs.
   (e) Removal of "m.p.h." signs on advisory speed signs.
   (f) "km/h" supplementary discs prepared.
   (g) Change to metric legal speed limits on signs.

2. Maps
   (a) Preparation
   (b) Availability

3. Vehicle equipment
   (a) Conversion aids, miles to kilometres.
   (b) Metric or dual speedometers and odometers required on new vehicles.
   (c) From January 1, 1975, all cars must have main metric speed limit markings on speedometers.

4. Traffic regulations and Vehicle construction regulations.
   (a) Consultation and discussion on conversions and finalizing of draft.
   (b) Regulations passed.
   (c) Road Code prepared and published
   (d) Metric traffic regulations effective.

5. Vehicle weight limits and heavy vehicle taxation.
   (a) Same as 4(a).
   (b) Weight regulations passed.
   (c) Heavy motor vehicle taxation report.
   (d) Taxation regulations.
   (e) Metric weight and tax regulations take effect.

In the area of signing, the changeover of distance and regulatory speed signs are on schedule while the metrication of advisory speed signs is ahead of schedule (B, 1, 127).

3.4.5 Canada

a. The Road Transport Association of Canada (RTAC) has proposed a plan for national metric conversion of road system (B, 1, 131). This plan has been reproduced in Table 9. Please note that the key given on the first page of section 3.4 does not apply to either of the Canadian tables.

b. In addition to the recommended schedule shown in Table 9, the RTAC has also drawn up a recommended schedule for the application of the metric system in Canada (B, 1, 131). This schedule is reproduced in Table 10.

Tables 9 and 10 form a plan which, if followed, will achieve "...complete metric conversion of Canada's highway systems" by the end of 1979 (B, 1, 131). Items listed in the first table will be provided by the RTAC, while metricated national standards (found in the second table) will have to be provided by such organizations as the Canadian Standards Association, the American Society for Testing and Materials, and the American Association of State Highway and Transportation Officials.

Being a relatively new plan, no information has been gathered indicating how closely the plan is being followed.

Table 9. RTAC's Proposed Plan for National Metric Conversion of Road Systems (Canada).

	Item	1973	1974	1975	1976	1977	Responsibility Assignment
Package one	1.(a)						MCC
	(b)						MCC
	(c)		As and when required				MCC
	2.						MCC
	3.(a)						MCC
	4.(a)						MCC
	5.(a)						MCC
	(b)						SC
	6.(a)						SC
	7.(a)						SC
	(b)		As and when required				SC
	(c)		As and when required				SC
	8.(a)						SC
	(b)		As and when required				SC
	9.(a)						CUTCD
	(b)						CUTCD
	(c)						CUTCD

Note: Table continued on following page.

Table 9 (Continued). RTAC's Proposed Plan for National Metric Conversion of Road Systems (Canada).

Item	1973	1974	1975	1976	1977	Responsibility Assignment
Package two 1.(a)						PROV. M.C.
(b)						PROV.
(c)						PROV.
(d)						PROV.
2.(a)						PROV.
3.(a)						PROV.
4.(a)						PROV.

Key to abbreviations:

RTAC: Road Transport Association of Canada
MCC: RTAC Metric Conversion Committee
SC: RTAC Standing Committee
M.C.: Metric Commission
PROV.: Road Agencies of the Province
CUTCD: RTAC Council on Uniform Traffic Control Devices for Canada

Explanation of items for Table 9.

Package One

1. General.
   (a) Guide to the introduction of the metric system to highway engineering operation.
   (b) Guide to metric units for construction.

2. Identification of National Standards Requiring Conversion.

3. Maps and Plans.
   (a) Metric Standards and guide for usage.

4. Engineering Surveys.
   (a) Guide for metric survey practices.

Explanation of items for Table 9 (continued).

3. Highway Signs.
   (a) Convert signs to metric distances and legal regulatory limits.

4. Weigh Scales.
   (a) Convert to metric units.

5. Geometric Standards.
   (a) Criteria for metric geometric design.
   (b) Metric conversion of RTAC geometric design manual.

6. Drainage Standards.
   (a) Criteria for metric drainage design.

7. Bridge Standards.
   (a) Criteria for metric bridge design.
   (b) Metric conversion of RTAC guide to bridge hydraulics.
   (c) Metric conversion of RTAC river bed scour.

8. Pavement Standards.
   (a) Criteria for metric pavement design.
   (b) Metric conversion of RTAC guide to the structural design of flexible and rigid pavements.

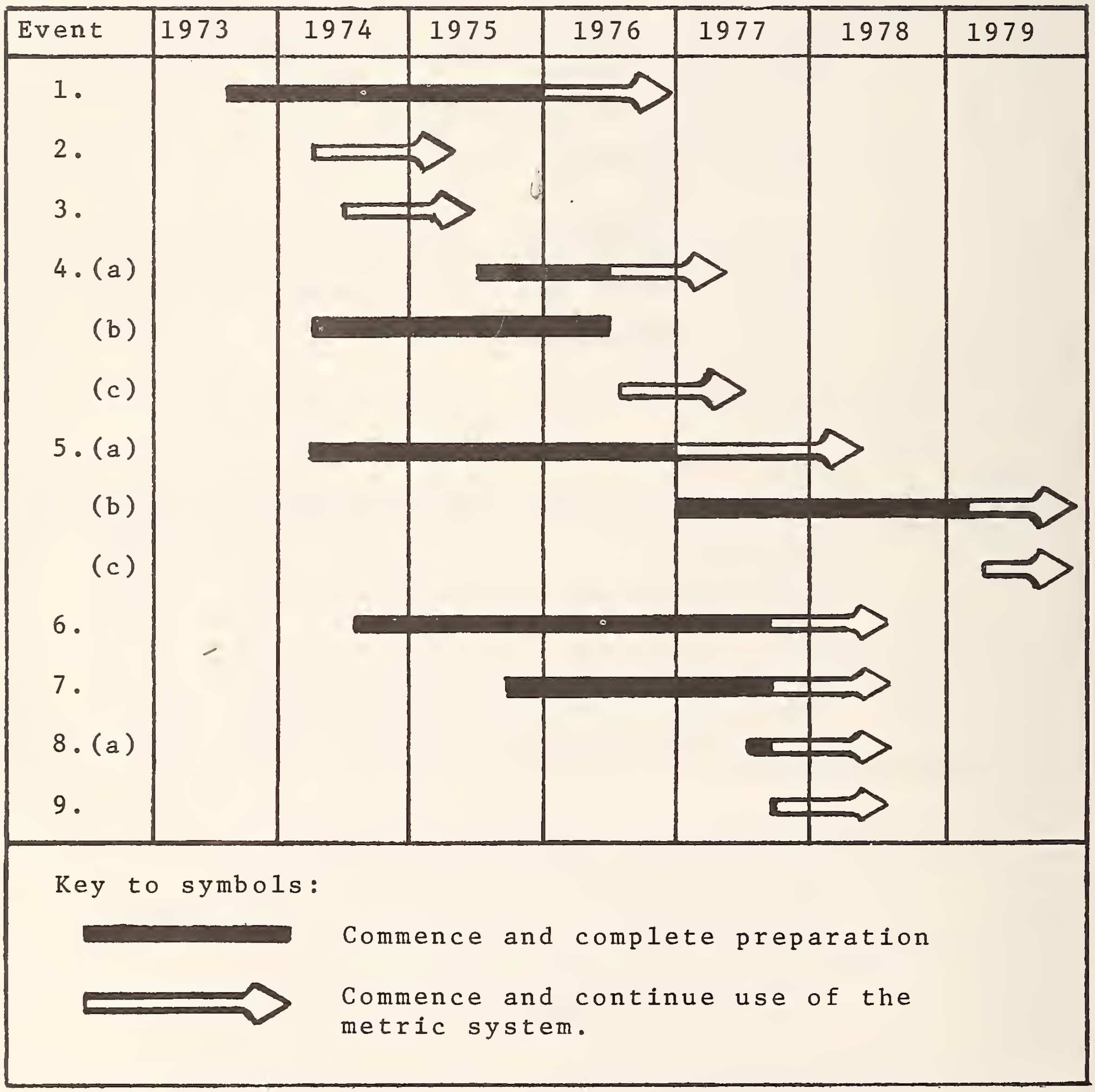
9. Signs and Traffic Control Devices.
   (a) Criteria for metric sign standards.
   (b) Guide for metric signing practices.
   (c) Metric conversion of RTAC manual of uniform traffic control devices.

<u>Package Two</u>

1. Public Education.
   (a) Awareness program.
   (b) Driver manuals.
   (c) Metric highway maps.
   (d) Speedometer conversion stickers.

2. Legislation.
   (a) Conversion to metric signing, operations, vehicle standards, weights and dimensions.

Table 10. RTAC's Recommended Schedule for Application of the Metric System (Canada).



Note: For explanation of events in Table 10 see following page.

Explanation of events in Table 10.

1. Re-orientation and Staff Training.

2. Control Survey.

3. Engineering Survey.

4. Planning and Design.
   (a) Agency in-house standards.
   (b) Establish national material standards required for design.
   (c) Physical design.

5. Construction.
   (a) Establish national construction standards required for construction.
   (b) Agency in-house specifications and contract documents.
   (c) Metric contracts.

6. Public Education.

7. Legislation.

8. Signing.
   (a) Physical changeover.

9. Maintenance and operation.

3.5 Metrication of Standards and Specifications

The last, but not the least, part of the metric conversion "on paper" is the changing of standards and specifications to the metric system of measurement.

3.5.1 Great Britain

Again, the British are more involved in this process than any other English speaking country and the major part of the available literature deals with their experience. Most of the requirements of the British highway industry are contained in three publications written by the Department of the Environment (DOE). These publications are: Roads in Urban Areas; Layout of Roads in Rural Areas; and Specification for Road and Bridge Works. About 180 requirements, in the form of standards, are produced by the British Standards Institution (BSI) (B, 2, 1).

Both the DOE and the BSI are in the final stages of converting their publications to metric, a process that has taken longer than expected. Although metric projects were acceptable after January 1, 1969, many standards and specifications were not metricated until 1972 and later. The procedures used by the DOE and the BSI to metricate their publications have been logical and straightforward. First, industry representatives, such as material producers, manufacturers, and trade associations, were called upon to contribute their ideas regarding conversion (such things as timetables, sizes, tolerances, units, etc.). These representatives along with the DOE and the BSI would then draft the new metric document and send it to higher authority for approval. However, revisions to the draft would often be needed, and sometimes as many as six or seven drafts were required before the final edition would be approved (B, 2, 1). This process consumed more time than expected and has caused residual delays.

Many counties throughout England follow the DOE and BSI publications to the letter when building 4-lane motorways (a system similar to our Interstate network). However,

for their own county roads the engineers often create their own set of specifications by taking the basic DOE and BSI requirements and making small refinements to suit their own districts. Therefore, delays in approving DOE and BSI documents also cause delays in writing county specifications because county engineers will wait for the new metric DOE and BSI documents before changing their own specifications. Such time lags have always existed, but the chain reaction concept is an important one that must be remembered when converting standards and specifications (B, 2, 11 and B, 2, 8).

It should be understood that one of the key features of the metric changeover is the development of metric standards (B, 2, 8). The BSI emphasizes that companies demand to know what the metric standards will be before they proceed with conversion. At present, about 1200 BSI standards have been metricated, and while many are changed by applying a direct metric equivalent, others are rationalized to even units, or have been changed into performance standards. However, one point remains consistent throughout the BSI, and that is the recommendation against dual dimensioning, because it is time consuming and very confusing (B, 2, 8).

The DOE handles its specifications in a similar fashion with some requirements being converted by applying a direct metric equivalent (soft conversion) and others changed to rational metric. On some materials they made it possible for the producer to continue manufacturing an Imperial product that would meet metric specifications by liberalizing tolerances (B, 2, 1). For instance, a standard 3 foot square road sign blank could be used as a metric road sign because the new specification would call for a 900 mm to 1 m square road sign blank. Again, while the DOE did not dual dimension their three main publications, mentioned earlier, they were published using Imperial units followed by empty brackets. As these publications were metricated, usually one at a time and in sections, the DOE would issue metric addendums and the holder of the publication would simply fill in the bracket with the proper

metric unit as listed in the addenda. This system appears to have worked quite well and complete metric editions of their specifications will soon be available (B, 2, 1).

With regards to design work, by the end of 1975 the British engineering industries expect to have 75% production in metric (B, 1, 89). In helping to achieve a goal of 100% metric engineering drawings the BSI has resolved one major problem by developing a set of standard metric scales. These rational metric scales consist of $1{:}10^n$, $1{:}2\times10^n$ and $1{:}5\times10^n$, where n is an integer (B, 1, 156). The complete recommended list is given in Table 11 (B, 1, 56).

The scales marked by an asterisk (1:2500 and 1:1250) in Table 11 are traditional mapping scales used by the Ordnance Survey. They have been included in addition to the rational scales because it is considered impractical for the Survey to adopt new scales within the foreseeable future.

These scales have been widely accepted with very little complaint. However, some designers feel that a scale between the 1:20 and 1:50 scales would be useful for small detailing work. They suggest that a 1:25 or a 1:30 scale (corresponding to 3/8 in. to 1 ft.) would be extremely useful (B, 2, 11). However no general agreement in this has been observed.

A design area of major importance to the DOE was the developing of metric roadway dimensions that would match, within reason, existing pavements. This is a good example of changing a specification to metric by first deriving the metric equivalent and then rationalizing that number to some convenient figure (hard or rational conversion). Their recommended dimensions are given in Table 12 (B, 1, 40).

Metric specifications pertaining to highway field construction operations in Britain, as anywhere else, are of no major concern. The main problem of dimensional coordination, established in England and being developed more extensively here in the United States, is present in the building construction industry but not in road

Table 11. BSI Standard Metric Scales for Engineering Drawings.

USE		SCALE	NEAREST CURRENT FOOT/ INCH SCALES
	Maps	1:1 000 000	1:1 000 000
		1:500 000	1:625 000
		1:200 000	1:250 000
		1:100 000	1:126 720(1/2" to 1 mi.)
		1:50 000	1:63 360 (1" to 1 mi.)
	Town Surveys	1:50 000	1:63 360 (1" to 1 mi.)
		1:20 000	1:25 000
		1:10 000	1:10 560 (6" to 1 mi.)
		1: 5 000	- - -
		*1:2 500	1: 2 500
		1:2 000	- - -
Location Drawings	Block Plan	*1:2 500	1: 2 500
		1:2 000	- - -
		*1:1 250	1: 1 250
		1:1 000	- - -
	Site Plan	1:500	1:500
		1:200	1:192(1/16" to 1 ft.)
	General Location	1:200	1:192(1/16" to 1 ft.)
		1:100	1:96 (1/8 in.to 1 ft.)
		1:50	1:48 (1/4 in.to 1 ft.)
Component drawings	Ranges	1:100	1:96 (1/8 in.to 1 ft.)
		1:50	1:48 (1/4 in. to 1 ft.)
		1:20	1:24 (1/2 in. to 1 ft.)
	Assembly	1:20	1:24 (1/2 in. to 1 ft.)
		1:10	1:12 (1 in. to 1 ft.)
		1:5	1:4 (3 in. to 1 ft.)
	Details	1:10	1:12 (1 in. to 1 ft.)
		1:5	1:4 (3 in. to 1 ft.)
		1:1	1:1 (full size)

Table 12. Department of Environment (DOE) Recommended Roadway Widths (Great Britain).

A. Recommended carriageway widths for urban roads*

Road Type	Recommended carriageway widths m
Primary distributor	
Dual 4 lane carriageway	14·60
Overall width for 4 lane divided carriageway with central refuges	14·60
Single 4 lane carriageway with no refuges	13·50
Dual 3 lane carriageway	11·00
Single 3 lane carriageway (recommended only for tidal flows)	9·00
Dual 2 lane carriageway	7·30
District distributor	
Single 2 lane carriageway	7·30
Dual 2 lane carriageway	7·30
Dual 2 lane carriageway if the proportion of heavy commercial traffic if fairly low	6·75
Local distributor	
Single 2 lane carriageway in industrial districts	7·30
Single 2 lane carriageway in principal business districts	6·75
Minimum single 2 lane carriageway in residential districts used by heavy vehicles	6·00
Access roads	
In industrial and principal business districts use the dimensions stated above for local distributors Minimum width for single 2 lane carriageways in residential districts	5·50
2 lane width for back or service roads used occasionally for heavy vehicles	5·00
Minimum 2 lane width for back roads in residential districts if use is limited to cars	4·00

Table 12 (Continued). Department of Environment (DOE) Recommended Roadway Widths (Great Britain).

B. Recommended carriageway widths for rural roads

Road type	Recommended carriageway widths m
Single lane carriageway used principally in Scotland and Wales	3•6
Minimum width of carriageway in rural junctions	4•5
Minimum width for single 2 lane carriageway	5•5
Motorway slip road width	6•0
Single or dual 2 lane carriageway	7•3
Single 3 lane carriageway	10•0
Dual 3 lane carriageway	11•0
Dual 4 lane carriageway	14•6

C. Urban and rural roads: lay-bys, bus bays and passing bays

Type of lay-by	Width m
Minimum standard lay-by	2•5
General standard lay-by	3•0
Bus bay standard	3•25
Maximum standard for single carriageway lay-by	3•5
Standard passing bay	2•25

Table 12 (Continued). Department of Environment (DOE) Recommended Roadway Widths (Great Britain).

D. Recommended footway widths for urban and rural roads.

Type of road	Recommended minimum footway widths m
Primary distributor: Urban motorway All purpose road	 No footways 3.00*
District distributor	3.00 in principal business and industrial districts* 2.50 in residential districts*
Local distributor	3.00 in principal business and industrial districts* 2.00 in residential districts*
Access roads	Principal means of access: 3.00 in principal business districts* 2.00 in industrial districts* 2.00 normally in residential districts* 3.50-4.50 adjoining shopping frontages Secondary means of access: 1.00 verge instead of footway on roads in principal business and industrial districts 0.60 verge instead of footway on roads in residential districts

*If no footway is required provide verge at least 1m wide. Where slabs are used widths are net paved areas (excluding kerbs).

Table 12 (Continued). Department of Environment (DOE) Recommended Roadway Widths (Great Britain).

E. Cycle tracks and cycle ways for urban and rural roads

Type of Traffic	Standard Width m	Minimum Width m
One-way traffic	2·75	1·80
Two-way traffic	3·60	---

F. Pedestrian bridges and subways for urban and rural roads

Bridges, subways	Width m	Height m
Pedestrian bridges	1·80 (min for permanent structures) 1.50 (min for temporary structures)	see table "G" below
Subways	2·30	2·25

G. Vertical clearances for urban and rural roads

Obstruction	Minimum vertical clearance including allowance for resurfacing m
Overbridges	5·1
Sign gantries	5·5
Minimum maintained clearance	5·0

*Tables A to G are taken from Ministry of Transport Technical Memorandum T8/68.

construction (B, 1, 155). The two main areas of interest involving metrics in road construction are those of surveying and testing.

The Ordnance Survey produces maps in four main scales, 1:50000, 1:10000, 1:2500 and 1:1250 (B, 2, 13). It is felt that the 1:2500 and the 1:1250 scales will eventually be changed to 1:2000 and 1:1000, but this change is likely to be many decades away (B, 1, 32). Horizontal control in Britain is metric and has been for about 30 years; however, map contours are in feet. A program has been started to establish map contours in metres but it will take until 1990 to complete such an enormous task (B, 2, 13).

Survey crews are now using metres and millimetres for both horizontal and vertical control and have not found staking to be unduly difficult. Errors mainly occur in direct tape measuring due to more numbers being involved, and additions and subtractions should be done on paper to avoid mistakes. Other errors have resulted from simply juxtapositioning adjacent numbers (B, 1, 155). Initially, survey crews have found their work taking more time when done in metric but this is due to working with drawings in unfamiliar units, a problem which will improve with practice (B, 1, 155).

Contractors are favorable to drawings using the 1:10, 1:20, 1:50 and 1:100 scales, but here again recommend a scale between the 1:20 and 1:50 size. They suggest using a 1:33 1/3 for most detail drawing (B, 1, 155).

Testing standards have been slow in coming but once written they have been just as easy to work with as the old Imperial standards (B, 2, 12). Changes are required in some equipment, and laboratory personnel need to learn new units, but both of these problems are temporary.

There is, however, one major problem in testing standards dealing with sieve sizes. The International Standards Organization (ISO), along with many countries, has adopted a preferred number series, or Renard numbers,

based on the common ratios $\sqrt[5]{10}$, $\sqrt[10]{10}$, $\sqrt[20]{10}$, $\sqrt[40]{10}$. These numbers form the basis of the ISO recommendations, and the series is referred to as R5, R10, R20 and R40 (A, 2, 16). See Table 13.

Each series may be extended indefinitely in either direction. For sieve sizes ISO decided to use every sixth term of the R40 series and called these the Primary Sizes, see Figure 1 (B, 1, 109). Unfortunately, these Primary Sizes fall between the British Imperial sizes so in order to strike a closer match the ISO has issued a series of Supplementary Sizes, see Figure 2 (A). However, the BSI has proposed its own series of Primary and Intermediate Sizes by using every third term of the R40 series (with some rounding), see Figure 2(C). This system has the advantage that the Intermediate Sizes match with the old British Imperial sizes below an 1/8", and are very close to the old sizes above 1/8", see Figure 3 (B, 1, 109). Therefore, there has been a great deal of confusion, because sieve manufacturers started to produce the ISO sieve sizes and then learned of the formulation of the new British Standard sizes. As a result there has been much delay and expense connected with sieve work, which serves to illustrate the importance of leadership in metricating standards. A last point on this subject is one of completeness. When the new sieve sizes were finalized in Britain, related committees neglected to change the percentage passing requirements on standards concerned with graduation of aggregates. As a result producers were trying to meet old percent passing specifications by screening with new metric sieve sizes. The problems which resulted are obvious and the situation is now being corrected, however this is a good example of the necessity of metricating all interrelated standards at one time to prevent unnecessary problems (B, 2, 12).

3.5.2 Australia

Metrication of standards and specifications in other countries appears to be less complex than in Britain. The National Association of Australian State Road Authorities (NAASRA) has not found it necessary to publish detailed

Table 13. Basic Series of Preferred or Renard Numbers

Series	*Graduation (approx.)*	*Ratio*
R5	58%	1·58
R10	25%	1·25
R20	12%	1·12
R40	6%	1·06

R5	R10	R20	R40
100	100	100	100
			95
		90	90
			85
	80	80	80
			75
		71	71
			67
63	63	63	63
			60
		56	56
			53
	50	50	50
			47·5
		45	45
			42·5
40	40	40	40
			37·5
		35·5	35·5
			33·5
	31·5	31·5	31·5
			30
		28	28
			26·5
25	25	25	25
			23·6
		22·4	22·4
			21·2
	20	20	20
			19
		18	18
			17
16	16	16	16
			15
		14	14
			13·2
	12·5	12·5	12·5
			11·8
		11·2	11·2
			10·6
10	10	10	10

NOTE: The above series may be extended indefinitely in either direction by multiplying or dividing by 10, 100, 1000 and so on, e.g. below 10 the R40 series proceeds 9·5, 9·0, 8·5, 8·0 etc, and below 1 the series proceeds 0·950, 0·900 etc.

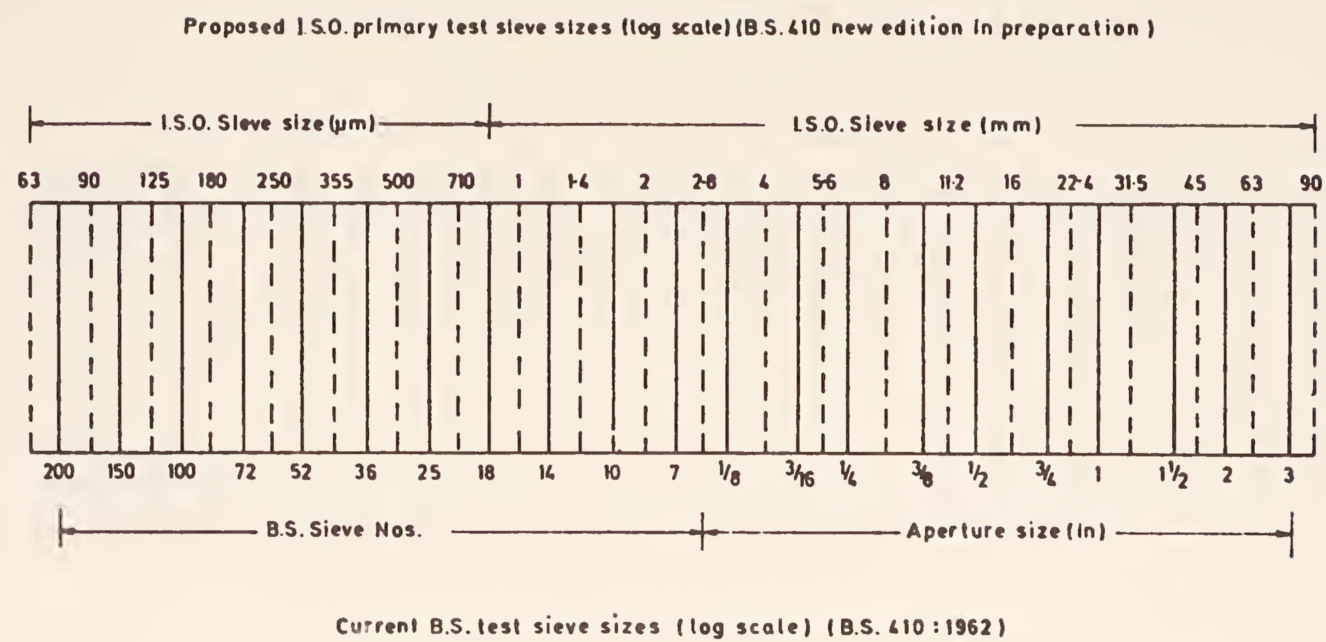


Figure 1. Relatio ween the primary ISO test sieve sizes and the B.S. test si izes used by the road engineering industry (Great in)

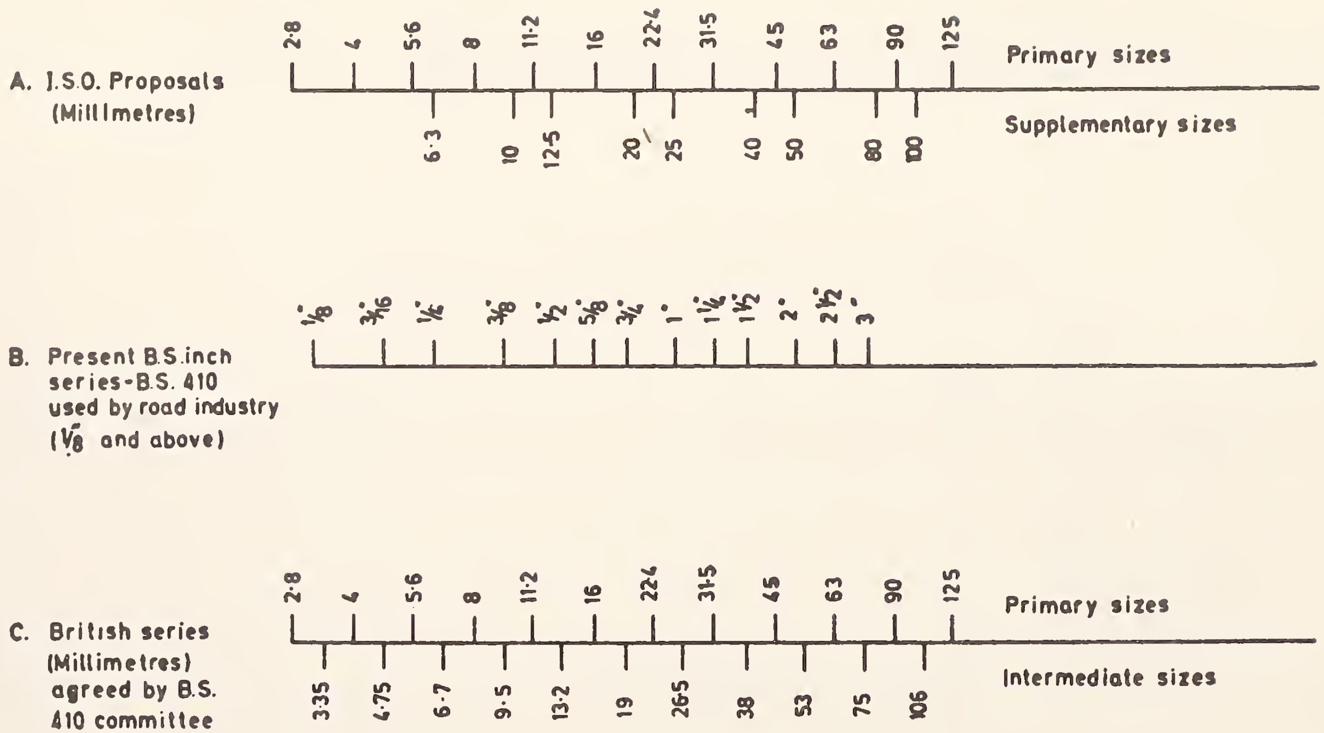


Figure 2. Comparison of the B.S. 410 test sieve series with the proposed ISO series and the B.S. metric series (Great Britain)

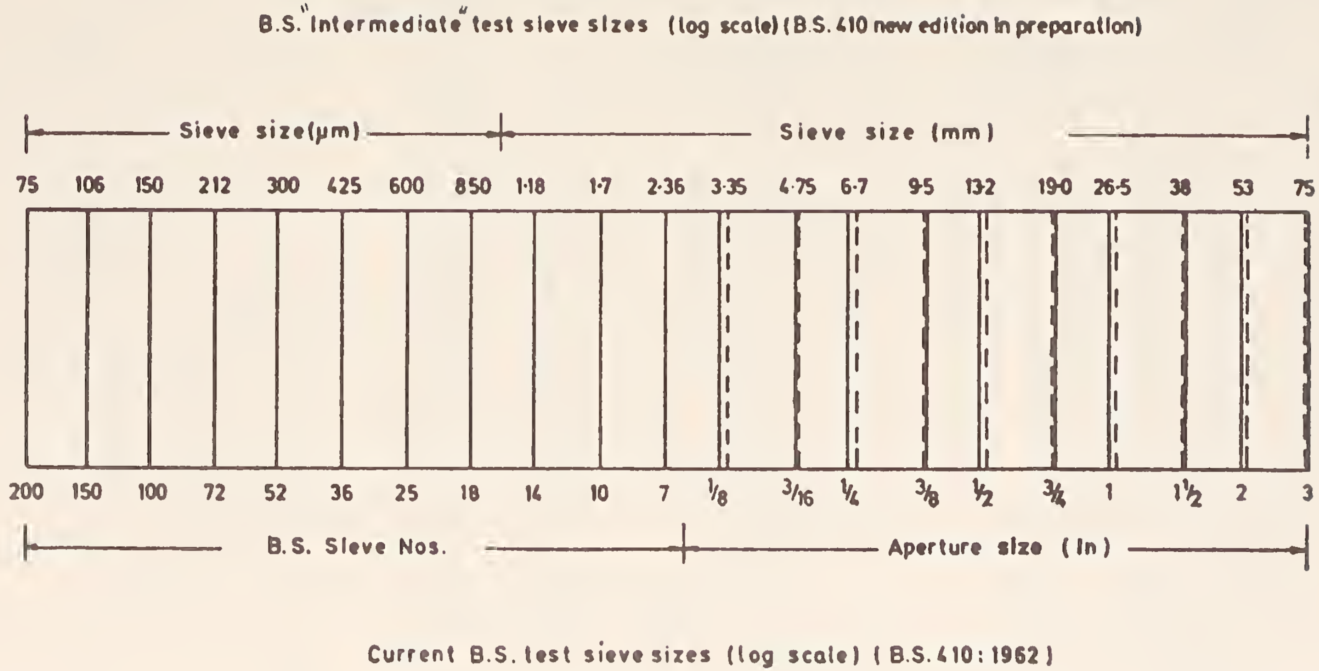


Figure 3. Relation between the proposed B.S. 'intermediate' test sieve sizes and the present B.S. test sieve sizes used by the road engineering industry (Great Britain)

programs for each area of the road construction industry. Instead, NAASRA has adopted the program of the Building and Construction Industry which was developed by the Metric Conversion Board (MCB). Standards used by NAASRA members are those written by the Standards Association of Australia (SAA). The only publication dealing with the change to metric released by the NAASRA was a small pamphlet on the subject of road signs. However, NAASRA has representatives on the MCB and the SAA committees so that points affecting the road authorities have been taken into account as standards have been metricated (A, 2, 42). The SAA has metricated their standards in the same way as the BSI. Most standards have been rationalized to even metric units with some standards using an exact metric equivalent. The MCB has issued a special list of plan scales, and they are as follows: 1:1, 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, 1:200, 1:500, 1:1000, 1:2000, 1:5000 and 1:10000. A 1:4000 scale is Standard for urban mapping, and a 1:8000 scale is used on survey plans (B, 1, 140). The New Zealand Metric Advisory Board has yet to approve their metric plan scales. However, they have been suggested, and will likely be approved, as shown in Table 14 (B, 1, 158).

Table 14. Metric Conversion Board's (Australia) Recommended Plan Scales

Use	Scale	Nearest Current ft/in scale	
Town Surveys	1:50 000	1:63 360	(1 in. to 1 mile)
	1:20 000	1:25 000	
	1:10 000	1:10 560	(6 in. to 1 mile)
Town Surveys	1: 2 500	1: 2 500	
Locality drawings	1: 2 000		
	1: 1 250	1: 1 250	
	1: 1 000		
Site plans and	1: 500	1: 500	
floor plans	1: 200	1: 192	(1/16" to 1'0")
	1: 100	1: 96	(1/8" to 1'0")
	1: 50	1: 48	(1/4" to 1'0")
	1: 20	1: 24	(1/2" to 1'0")
	1: 10	1: 12	(1" to 1'0")
	1: 5	1: 4	(3" to 1'0" 1/4 FS)
	1: 1	1: 1	(full size)

3.5.3 United States

Metrication of standards and specifications in the United States is in its infancy. The American Society for Testing and Materials has formed a Committee on Metric Practice and has published the well-known Metric Practice Guide (ASTM: E 380-72) since 1964 to aid in the process of conversion. Most of ASTM's 5000 standards have been "soft" converted, changed to equivalent metric units, but very few of their technical committees have produced "hard" converted standards, that is, the process of developing completely new metric standards (A, 2, 9).

A few of the larger industries in the United States have embarked upon the road to metric. In particular, General Motors Corporation, Ford Motor Company and American Motors Corporation have "soft" converted their specifications and have firm programs established leading to total metric changeover. The oil and steel industries will now "soft" convert their products for consumers. A few of the major heavy construction equipment manufacturers have begun programs of switching to metrics. In particular the Caterpillar Tractor Company has not only "soft" converted but has begun a program of "hard" changeover to metrics (A, 3, 28). However, many companies, including those mentioned, are afraid to move too quickly, or indeed, to even enter a conversion program, because of lack of Governmental leadership.

Unites States participation on ISO committees is voluntary and is not directly supported by the Government. We participate on about 70% of the ISO technical committees, and on about 50% of the subcommittees and working groups (B, 1, 31). However, it is evident that Government action is necessary before metric conversion of standards and specifications can swing into high gear in the United States.

3.6 Metrication of Highway Materials

As the metrication of standards and specifications is being completed the manufacturing and field operations of the changeover can begin. At this point three separate phases of the metrication process must occur almost simultaneously. They are metrication of materials, metrication of equipment, and the retraining of personnel. This section will examine how other countries have approached the task of metricating some of the more important highway materials.

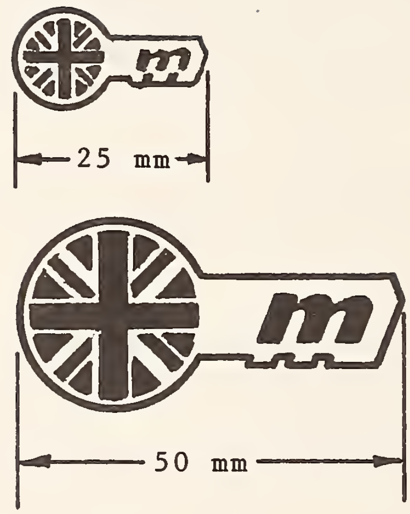
Again, Great Britain has done more, in recent years, to change its materials to metric than any other single country, due mainly to the timetable that the U.K. has followed. In the early 1970's most suppliers had input with government designers as to making the changeover to metric units in their product lines. In fact most suppliers were glad to be prodded into changing as they felt someone had finally taken the lead and was giving some direction to the change. Assurances were heard that far from the metric parts costing more, the penalty would be on those staying with imperial sized materials (B, 1, 46). Unfortunately, in 1971 a change in government party power and runaway inflation slowed the momentum of metrication (B, 2, 1). As a result some energetic firms already producing metric materials suffered financially due to a decline in metric material demands (B, 1, 46). However, these problems were not due to metrication and undoubtedly would have occurred no matter what units materials carried. In spite of difficulties, material changeover deadlines were met and business is now increasing. Construction organizations report that there were no difficulties in obtaining metric materials (B, 2, 11).

Material changeover in Australia has been much more recent, mostly in 1973, and has experienced fewer problems. Some materials have been "soft" converted as an interim process while awaiting the formulation of definitive national or international dimensions. However, in most cases materials have experienced a "hard" changeover after careful

consideration was given to the user and the products effect on other dependent materials. Preferred metric sizes of key products were determined after consultation with designers, manufacturers, users, regulatory authorities, and international standards (B, 1, 85).

New Zealand has indicated a strong willingness to metricate their engineering raw materials and some suppliers are now selling metric products. Initial supplies of metric materials are being imported from Australia, but it is hoped that New Zealand will begin producing her own metric materials in the near future. Indeed, the Metric Advisory Board warns that manufacturers may find it difficult to purchase imperial materials at competitive prices as time goes on (B, 1, 127).

As material changeover proceeds, it must be realized that both imperial and metric materials will show up side by side on a job site affected by the switch. Since many items are likely to be about the same size an identification process is required. In Britain it was suggested that the Metrication Board devise a uniform national identification scheme applicable to all metric articles. However, this idea was ruled impractical due to the large variety of products, the problems of marking, and conflict with means of product identification already established. It was concluded that each company would develop their own identification scheme or follow the system recommended by the British Standards Institution. The BSI developed a key symbol (see figure 4) to be used on any article that was wholly metric and not imported. The symbol does not imply compliance with a British Standard. The Ministry of Defense uses the symbol M for metric articles. Metric products too small to mark are identified by the color blue. As the changeover proceeds there will be less need for identification and in view of that fact the British suggest a plan that other countries might use, at least on some items. Mark the imperial rather than the metric items. This scheme has two advantages: one, identification requirements are kept to a minimum since only the declining numbers of imperial items need to be marked, and two, the identification scheme



The metric key sign was introduced by BSI in 1967, and is intended for use nationally to symbolize the metric changeover in the United Kingdom. BSI uses it extensively for its own publicity work on metrication and many firms are now including the symbol in their letterheads, catalogues and trade advertising (B, 1, 90).

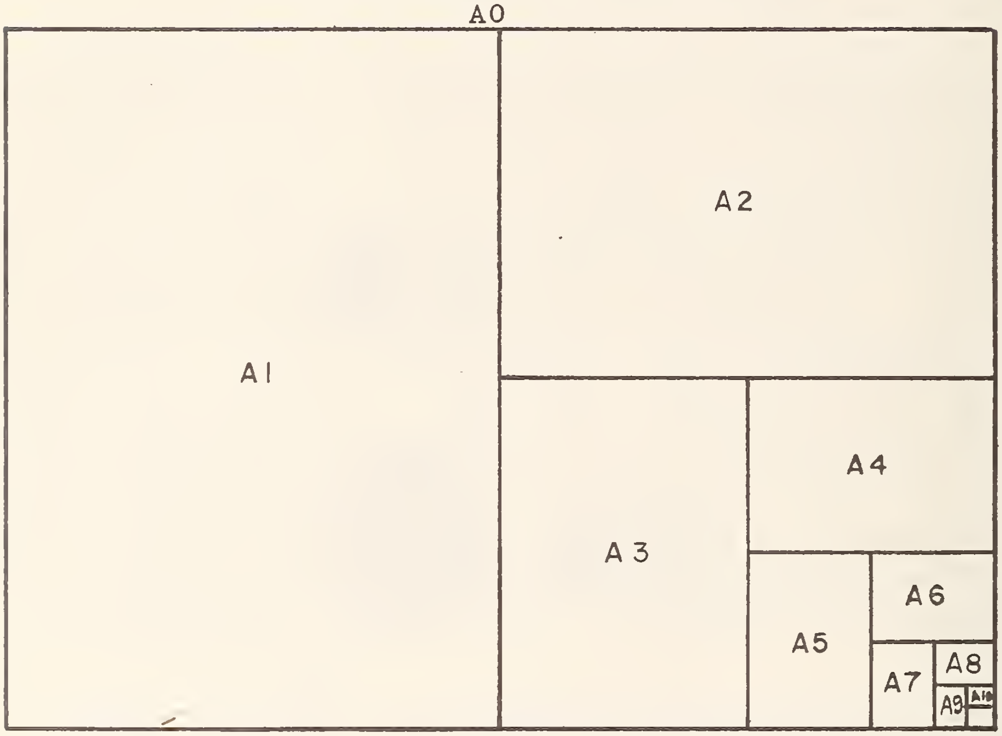
Figure 4. British Standards Institute (BSI) Key Symbol.

disappears automatically when imperial items are no longer stocked (B, 1, 86).

The International Organization for Standardization (ISO) has developed a number of material standards that have been accepted by all metric countries. One such standard is the A-series paper standard. Its use standardized letter and drawing sizes throughout industry, and permits dealers and users to reduce their paper stocks by an estimated 50% (B, 1, 50). The basic size of the A-series is derived from a rectangle, A0 having a surface area of 1 m^2 on the basis of two rectangles, $X:Y = 1:\sqrt{2}$ and $XxY = 1$(i.e., x = 841 mm; y = 1189 mm) (B, 1, 40). See table 15 (B, 1, 90). There is a secondary range of paper sizes known as the B-series. Each B size falls about half way between two A sizes, and the B sizes are intended to be used only in unusual conditions such as posters or wall charts. See table 16 (B, 1, 64). Also, there is a C-series of envelope sizes expressly designed to work with the A-series of paper sizes. See table 17 (B, 1, 64).

Most bulk construction materials, such as earth, timber and concrete are now being talked about in m^3 (B, 2, 3). As an example, British concrete suppliers switched to metric on January 1, 1971 (aggregates sold by tonne switched the same day) and began speaking about concrete in completely new terms. Cement is shipped in 50 kg bags, and instead of ordering so many cubic yards of class C, 3/4" aggregate concrete, one now orders so many cubic metres of 21/20, which stands for 21 N/sq. mm (or 21 MN/sq. m) compressive strength concrete using 20 mm aggregate (B, 2, 12). Most suppliers will still fill cubic yard orders by simply converting them to metric and one company's chart can be seen in table 18 (B, 1, 30). Australian concrete suppliers switched to metric on July 1, 1973 in a slightly different way than the British. Cement is shipped in 40 kg bags, volume is in cubic metres, and aggregate is in mm; but compressive strength is in megapascals and the metric strengths have been rationalized as shown in table 19 (B, 1, 85). Still other materials, such as concrete pipe, have not been rationalized. Both Great Britain and

Table 15. Isometric Paper Sizes. The "A" Series of ISO Trimmed Paper Sizes.



The International A-series of paper sizes, trimmed sizes are as follows:

A size	mm
A0	841x 1189
A1	594x 841
A2	420x 594
A3	297x 420
A4	210x 297
A5	148x 210
A6	105x 148
A7	74x 105
A8	52x 74
A9	37x 52
A10	26x 37

Tolerances

Trimmed sizes are subject to the following tolerances:

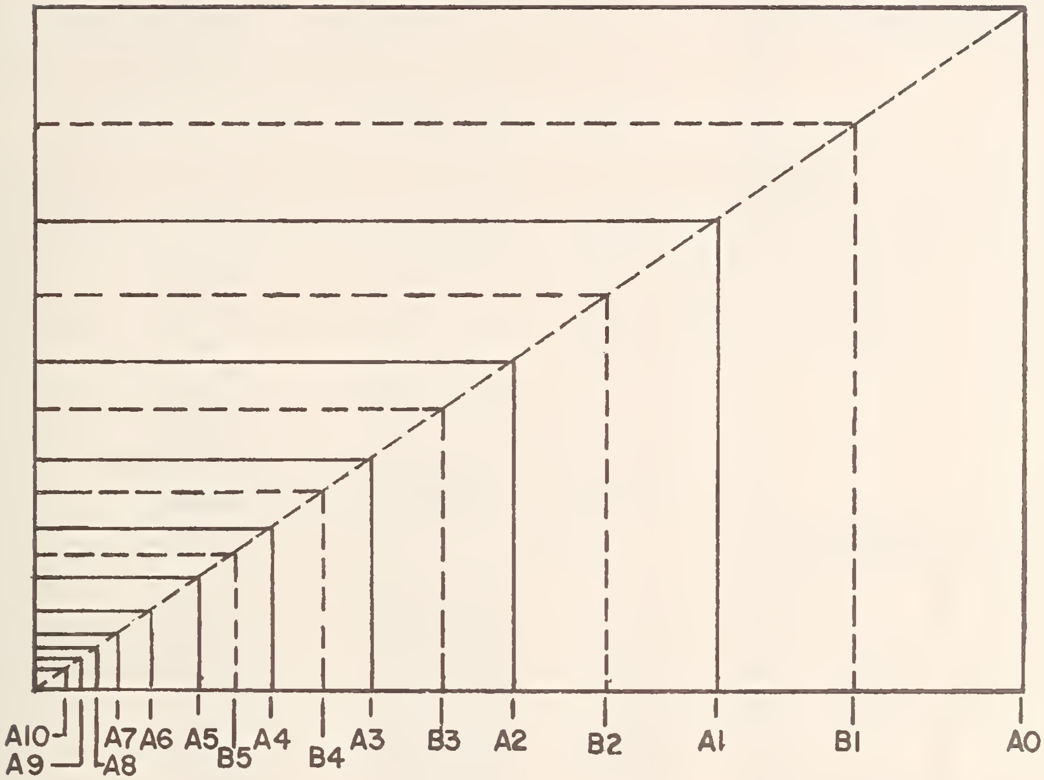
for dimensions up to and including 150mm$\pm$1.5mm

for dimensions greater than 150 and up to and including 600mm$\pm$2mm

for dimensions greater than 600mm$\pm$3mm

It will be noted that smaller sizes are obtained by halving the larger dimension of the sheet above and larger sizes by doubling the smaller dimension of the sheet size below.

Table 16. Isometric Paper Sizes. The "B" Series of ISO Trimmed Paper Sizes.

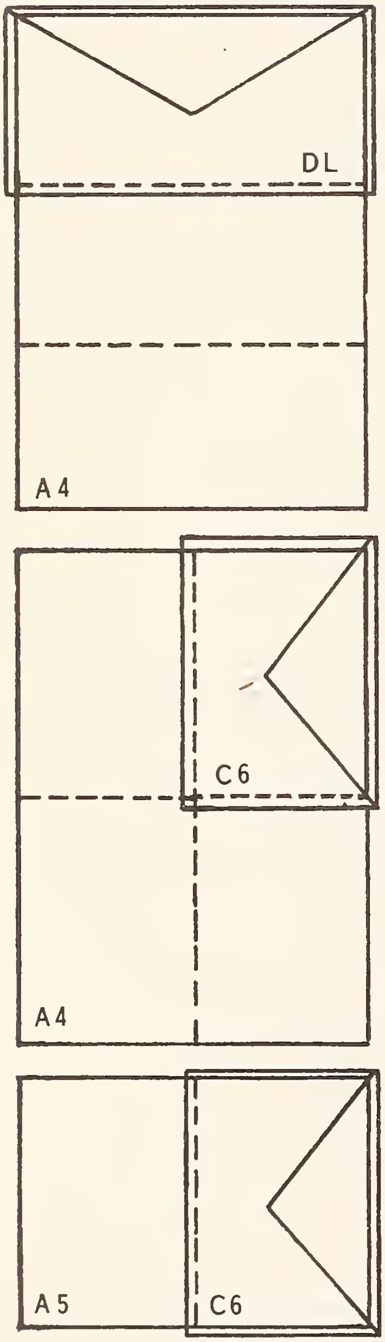


Note that all sizes are proportional

ISO "B" Series
(trimmed)

Symbol	millimetres
B0	1000x1414
B1	707x1000
B2	500x 707
B3	353x 500
B4	250x 353
B5	176x 250
B6	125x 176
B7	88x 125
B8	62x 88
B9	44x 62
B10	31x 44

Table 17. Isometric Paper Sizes. The "C" Series of ISO Envelope Sizes.



Envelope symbol	Envelope dimensions	Enclosure symbol
C7	81x114mm	A7
C7/6	81x162	1/3A5b(or 2/3A6)
DL	110x220	1/3A4b(or 2/3A5)
C6	114x162	A6
B6	125x176	C6
B6/C4	125x324	1/2A4
C5	162x229	A5
B5	176x250	C5
C4	229x324	A4
B4	250x353	C4
C3	324x458	A3

Table 18. Concrete Strength Chart (British).

lbs.per square inch	Actual N/sq.mm equivalent	Recommended N/sq.mm version
1000	6.89	7.0
1250	8.62	9.0
1400	9.65	10.0
1500	10.34	10.5
1600	11.03	11.5
1800	12.41	12.5
2000	13.79	14.0
2250	15.51	16.0
2400	16.54	17.0
2500	17.24	17.5
2750	18.96	19.0
3000	20.68	21.0
3250	22.41	22.5
3500	24.13	24.5
3600	24.82	25.0
3750	25.86	26.0
4000	27.58	28.0
4200	28.96	29.0
4500	31.03	31.5
5000	34.47	34.5
5500	37.92	38.0
6000	41.37	41.5
7500	51.71	52.0
8000	55.16	55.5

Note:

The actual N/sq.mm equivalent is shown to two places of decimals based on 1 lb. per square inch equalling 0.0068947 N/sq.mm

Table 19. Specified Characteristic Strength of Concrete at 28 Days (Australian)

Grade designation	Strength	
	MPa	lbf/in^2
Compressive strength		
15	15	2200
20	20	2900
25	25	3600
30	30	4400
40	40	5800
50	50	7300

Australia have decided to use near equivalent metric sizes of concrete pipe. Both countries have a 100 mm (inside) diameter pipe followed by 150 mm to 1200 mm sizes in 75 mm increments, and 1200 to 1800 mm sizes in 150 mm increments (B, 2, 16) (B, 1, 23). The British have liberalized tolerances in order to match old imperial and new metric pipe, they have given approval to produce a few 75 mm increment sizes above 1200 mm during the transition period, and they are allowing ten years for the industry to acquire complete metric molds (B, 2, 16).

In Britain, the first major industry to adopt the metric system for its products was the steel industry. Metrication of reinforcement bars was completed in 1972 (B, 1, 51). See table 20 (A) (B, 1, 28). In April, 1972 the tonne and the kilogram were adopted by the industry for all forms of steel sold by weight. During the same year the changeover to metric production of steel sheet and plate was completed (B, 1, 51), with angles following in 1973 (B, 1, 54). The changeover of steel bars has been a long slow process beginning in 1972 and extending to January 1, 1975 (B, 2, 7). However, the largest delay has been with hot-rolled sections. Steel shapes are still rolled to imperial dimensions but listed in metric terms (B, 2, 5), and production is likely to continue in the same manner until agreement on international standards is reached (B, 1, 54). Australia metricated its steel industry in 1973; a list of reinforcement bars is shown in table 20 (B) (B, 1, 85). However, they are also waiting for an international standard to be finalized for hot-rolled sections, and as a result have also "soft" converted their imperial section sizes (B, 1, 85).

On the whole, metrication of construction materials does not pose many major problems as long as the changeover programs are coordinated and controlled. In most cases the changeover will permit a reduction in the number of types and sizes of a material which should reduce costs. For example, one British company, a few years before metrication, held an inventory of over 3,000 types of screwed fasteners. Today after three years of metrication their total variety

Table 20. Metrication of Reinforcement Bars

A. British

DIMENSIONS FOR DEFORMED BARS					
Nominal Bar Size mm	Dimensions of Bar mm			Cross Sectional Area mm^2	Weight Kg per m
	A	B	C		
6	6.86	6.27	4.32	28.3	0.222
8	9.68	8.05	5.26	50.3	0.395
10	10.01	11.28	6.23	78.5	0.616
12	12.14	13.41	7.34	113.1	0.888
16	16.31	18.01	10.70	201.1	1.579
20	20.73	22.25	13.09	314.2	2.466
25	26.19	27.76	17.55	490.9	3.854
32	33.29	35.57	20.50	804.2	6.313
40	41.95	44.21	25.28	1256.6	9.864
50	52.53	55.70	34.98	1963.5	15.413

Note: A=Diameter across longitudinal rib.
B=Diameter perpendicular to longitudinal rib.
C=Pitch of deformation.

B. Australian

DIMENSIONS OF DEFORMED REINFORCING BARS

Size mm	Area mm^2	Mass per unit length kg/m
12	110	0.888
16	200	1.579
20	310	2.466
24	450	3.551
28	620	4.834
32	800	6.313
36	1020	7.991
40	1260	9.864
50	1960	15.413

of metric screws is 65 and it is unlikely to ever reach 200 (B, 1, 46).

In the United States, as in other countries, it must be remembered that most construction materials are not major products of export. Therefore, many materials can be metricated on a within-country basis without worldwide standards. The results of our U.S. highway construction material manufacturers survey seem to confirm this conclusion (see Appendix A, 4). Half of the companies that responded to our letters are engaged in metric conversion of their product. Under close examination it was found that companies producing metric products that are unique or independent of other items used a "hard" metric changeover even if the product is sold worldwide. However, companies producing metric products that are connected with other items and are sold world-wide, such as steel, are using a "soft" conversion, at the moment, until world standards are approved and final decisions are made in the United States as to metrication.

3.7 Metrication of Highway Equipment

As was mentioned in the preceding section metrication of equipment goes hand in hand with metrication of materials and the retraining of personnel. This section will illustrate some metric equipment and explain how the metrication process was achieved in other countries.

Again, it is important to identify metric equipment for the same reasons expressed earlier regarding metric materials. Since metric equipment may be found alongside imperial equipment on a project site, and realizing that it may appear identical, it is imperative that a system of identification be established. Once more the British Standards Institution suggests that metric equipment be marked with either BSI key symbol or the or the symbol M as shown in the previous section. For equipment in transition a symbol such as M/I, used by the Ministry of Defense, would suffice. In most cases a symbol will be adequate for indicating the proper servicing and maintenance of a

machine, with more detailed information being provided by handbooks or technical literature (B, 1, 86). The entire concept of identification is simple but at the same time very important. Most manufacturers will find it necessary to maintain dual inventories for many years to come and therefore will need to devise methods by which to differentiate stock.

Proper metric office equipment is essential to the sucessful operation of any progressive company headquarters. Information from England, Australia, New Zealand, and South Africa would indicate that there are adjustments but no complex problems in metricating an office. Producers have discontinued imperial paper sizes and now produce the metric A size sheets. In turn the manufacturers of drawing boards, reference tables and plan chests are now making versions to accomodate the A size. Even metric drafting machines and calculators are now in plentiful supply (B, 1, 50).

An idea, that started in Australia and spread to other countries in various forms, has helped provide a smooth transition period. A number of engineering organizations in Australia started a non-profit agency to coordinate such things as the publication and manufacturing metric design aids. The agency was used as a clearing house for ideas on how and when such things as scales and paper would be metricated (B, 1, 128).

As a result of this kind of organization it was discovered that many pieces of equipment could be modified into metric at very little cost. One British county engineer discovered that some of his special calculators could be converted to metric with only a few minor adjustments. He reasoned that machines do wear out and must be replaced; he had in fact acquired "new" metric machines by only performing a few adjustments at a comparatively low cost. While he might be converting them before new machines were actually needed, he felt that there was really no additional cost in his office converting to metrics (B, 2, 11).

Other types of office equipment, besides calculators, can also be converted. Officials report that planimeters can be recalibrated (B, 2, 11), and that some types of drafting machines can be modified to metric. Some parallelogram machines can be extended by a single change of links to extend the arm length, and many rail type machines need only a new vertical rail to extend their range (B, 1, 84). Such modifications are necessary because the new metric A-series paper sizes are larger than the old imperial sheets. At first this fact led to a problem with the old drafting board sizes; the paper was usually too big, in one direction, for the drawing surface. However, a British firm designed drawing board expansion kits that can easily be mounted on existing boards to extend their usefulness (B, 1, 100).

Two awkward problems have arisen in the drawing office despite careful planning. "The adoption of metric sizes for drawing sheets and office paper has resulted in a costly changeover of filing cabinets and much office furniture" (B, 1, 46). Some feel that this has been one of the biggest changeover problems and yet it is really small (B, 2, 1). The second problem is that these new paper sizes require a complete change in reproduction machinery, and this is surely one of the straight costs of metrication that should be coordinated with the depreciation of existing copying machines.

Metric scales are easy to produce and are plentiful in metric countries. They are available in many different combinations of scales and some producers use colors (the entire scale is a solid color with the divisions pressed on) so that draftsmen can identify the scales more readily and save time (B, 1, 141). At first some countries tried printing both the imperial and metric scales on the ruler (one on each edge). They soon discovered that the draftsmen were simply not using the metric edge but were using the imperial scale as a crutch. Production of dual dimensioned scales was soon halted.

Of all the equipment that needs to be metricated most

authorities agree that the most important is measuring equipment, namely surveying equipment (A, 2, 15). Yet again, this process has been simplified because all of the countries studied are remaining on the degree, minute, second system of angular measurement. As a result, only hand-held measuring devices need be converted and this can be done to some items, such as levelling rods and range poles, by applying a metric cloth overlay tape to the equipment. As this equipment wears out it can be replaced with metric. As an example, the Great Britain Ministry of Public Building and Works (MPBW) issues the following list of equipment for use by its crews (B, 1, 90):

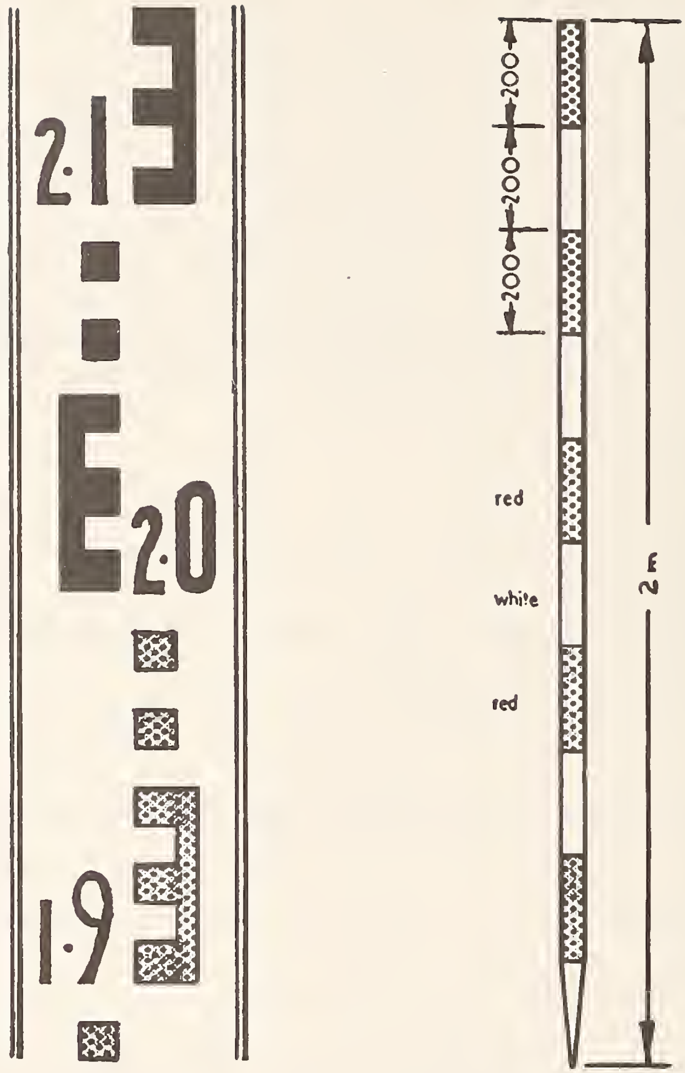
- coated steel tape, 30 m, steel case
- synthetic material tape, 20 m, leather case
- multi-folding wood rod, 2 m, six-fold
- land chains, 20 m
- levelling staffs, "E" type, 4 m telescopic, wood
- for site control only:
    150 mm scales
    1 m wood folding rules.

The Ordnance Survey issues similar equipment to its crews (B, 2, 13).

The following is a list of some of the most common equipment used by those countries studied (See Figure 5) (B, 1, 40; B, 1, 158; B, 1, 25):

1.) Folding Rules: one and two metre lengths
2.) Pocket tape rules: 1 m, 2 m, 3 m, 5 m
3.) Steel and synthetic tapes: 10 m, 20 m, 30 m
    (etched steel available in 30 mm and 50 m lengths)
4.) Chains: 20 m
5.) Levelling Staffs: 3 m, 4 m, 5 m
6.) Range rods: 2 m, 2.5 m, 3 m

Metricating field construction equipment would appear to be the easiest and least expensive of all equipment metrication. Personal tools of a workman that need metricating are quite a few; perhaps a folding rule and a



Levelling staff marked in 10 mm increments

Metric ranging rod

Figure 5. Metric Surveying Equipment Used by Most Foreign Countries.

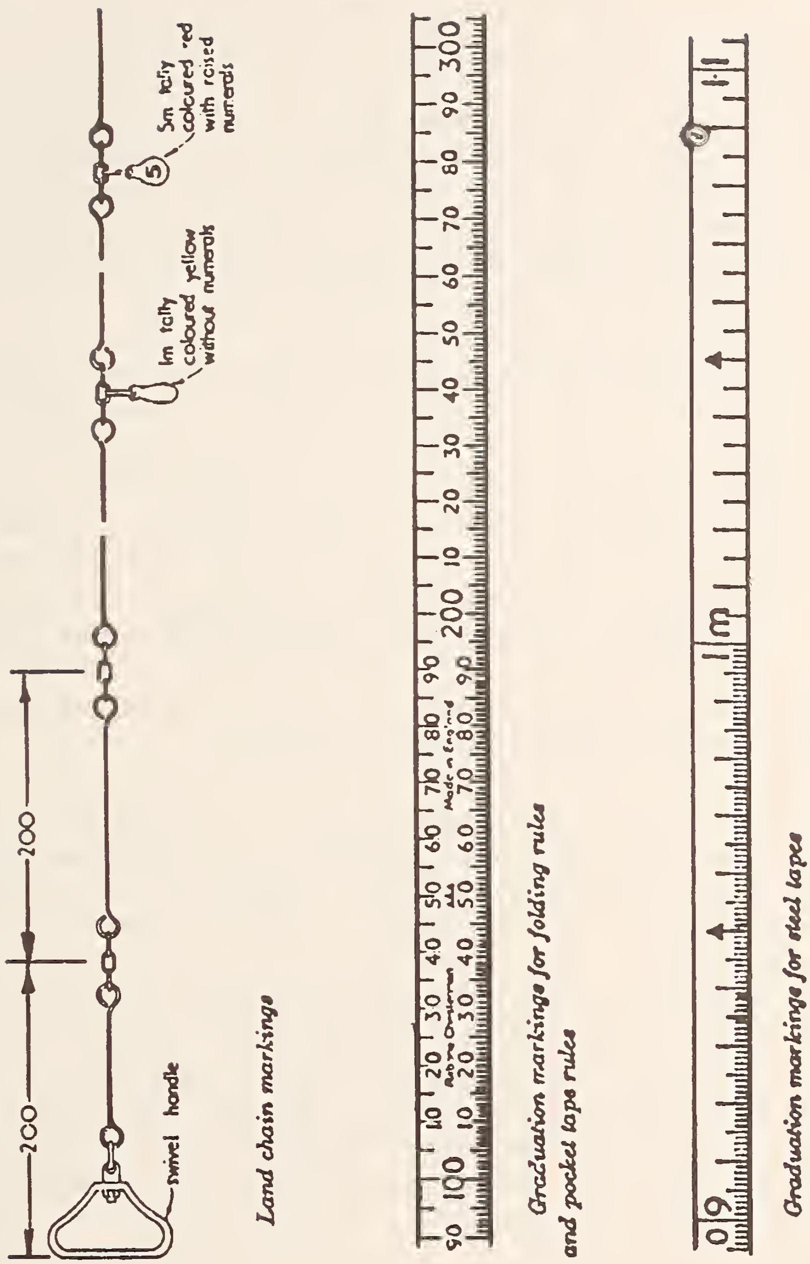


Figure 5 (Continued). Metric Surveying Equipment Used by Most Foreign Countries.

pocket tape and a number of wrenches (B, 2, 1 and B, 2, 3).

Private companies appear to have handled the metrication of heavy field construction equipment with ease. Most firms reported that they were able to modify their equipment to meet metric specifications. For example, the new metric pavement widths are very close to the old existing pavement dimensions. Most paving machines have side adjustment plates which were moved to the new required width. When these plates did not extend far enough it was no major task to cut and weld new plates (B, 2, 7 and B, 2, 12). Likewise, modifications could be made in wheel-type trenching machines to cut a metric width trench. For example, one British contractor was required to trench 15 miles of French drains. The project was metric and called for a trench width that was between 2 of his old imperial bucket sizes. As the backfill equipment is quite expensive he wanted to make sure he would cut the proper trench width; no more and no less. Therefore, he simply welded side cutters on the sides of the buckets in order to cut the correct width. Obviously, this same type of procedure would work on many crane or backhoe buckets (B, 2, 12).

On the job site the contractor is only concerned with the end product the machine produces, it matters not whether the engine is imperial or metric. However, in the shop, maintenance becomes the question. At present, this question is well answered by the fact that dual parts inventories are maintained for construction equipment in all countries studied. Most manufacturers intend to continue to stock imperial parts for twenty years after the date they convert. When you need a part you simply include the year and make of your machine and the proper component will be supplied. To this moment there have been no problems obtaining parts (B, 2, 12).

Metrication poses more of a problem to equipment used in manufacturing construction products or other construction equipment, and testing or research equipment, than it does to equipment in the field. Manufacturing or testing equipment is usually of very high quality and made to last a long

time. As a result, it usually represents a major capital investment and owners are unwilling to "junk it" at their own expense just for the sake of metrication.

Before conversion, countries that were not metric, in this case primarily Great Britain, began to notice that the demand for equipment was growing in metric countries. When metrication was decided upon as a national policy the Federation of Manufacturers of Construction Equipment , in England, was for the conversion but wanted to approach the subject with caution. A rapid conversion would be a financial disaster for any country, as one must understand all industry cannot go metric at one time. With this in mind it would appear that Britain's timetable, considered delayed, could be no faster without paying an enormous price (B, 2, 7). In fact one comment was that the British Standards Institution was in no hurry to produce metric standards because it would have been impossible for industry to meet those standards at the time (B, 2, 11).

It would appear that the most logical conversion plan would be to allow producers to use their equipment up until a specific date; after which all products would require a "hard" metric changeover. This would give the producers notice of future events so that they can plan an intelligent conversion, and at the same time allow them to operate under more liberal tolerances.

In the United States, much of our construction equipment production is exported to metric countries. We could export much more if the products were metric. The results of our U.S. highway construction equipment manufacturers survey show a heavy trend toward metrication. Over 2/3 of the companies that responded to our letter are engaged in some form of metric conversion. Under closer examination it was found that the companies with the most interest in converting to metrics were those who produced earth moving equipment, cranes, graders and backhoes; companies who would likely export in quantity. Some foreign countries have commenced to build plants in the United States

that will manufacture metric equipment. These occurrences seem to indicate that it is long past the time for U.S. conversion to the metric system.

3.8 Metric Training of Personnel

Most of this section and this entire report as well, reviews British literature on metrication. To get a better perspective on their approaches, methods and experience in metric training, and to be able to draw conclusions pertinent to metric training in the U.S.A., the reader should be aware of some conditions related to metric education which are true for Great Britain, but not for the U.S.A.

Most everybody in Great Britain had done a certain amount of work in metric long before metrication started. Britain was in the state of anticipation of metrication since the 1920's, and this was reflected in their elementary school programs; for example, rulers with imperial units on one side and metric units on the other (B, 2, 11), arithmetic problems in either system were given, etc.

Britain switched to decimal currency in 1971. This could be regarded as an exercise in changeover, establishment of a more positive attitude to a global change, and gaining of some practice with decimal numbers. Incidentally, this also created some negative attitudes towards change, which still persist to such a degree that British government has not yet metricated traffic signs, nor " anything that impinges on to the public" (B, 2, 1). Finally, British intercourse with predominatly metric continental European countries, through trade and tourism (and war), contributed to an increased familiarity with metric units in various segments of the British society. All the above conditions make metric training less serious of a problem in Britain relative to the U.S.A.

Metric training in engineering and in the construction industry is very much affected by how the country's educational system prepares the future laborers, technicians and engineers. Our sources indicate that primary education in

Great Britain now teaches metric as a matter of course, even though "there's still a variety of individual rates of progress within the overall pattern" (B, 2, 2), due to a decentralized school system. Secondary schools are "inching towards metric": programs are mixed (both imperial and metric), but public exams have been in metric since 1973. Universities were shifted to teaching in metric units "by 1966 or 1967" (B, 2, 3). So the primary concern of British metric retraining effort has been directed towards those who had completed their training before the late sixties and have built up an experience in imperial units.

3.8.1 Approaches to Metric Training

These approaches to training can be applied singly or in combination:

(a) self training, assisted by literature,
(b) on-the-job training, individually or in a group directly related to project work,
(c) formal internal training program, and
(d) external training through suitable courses or seminars, during or outside the normal working hours (B, 1, 85).

Our sources cite some differences in national approaches to metric training: while the South African program assigned each individual the full responsibility of training himself (the "sink-or-swim" approach), the British opted for "organizational responsibility for considerable formal and on-the-job training) (B, 1, 85). Australia and New Zealand lean towards the British stand. While it is not known how many sunk in South Africa, it is known that there was some overtraining in Britian, as well as "some negative reaction where no metric work was available to test newly acquired skills" (B, 1, 85). It is clear that different types of jobs would require different combinations of individual and organizational responsibility, including the extremes; however, total reliance on an individual, even for the best educated staff members, might have some undesirable consequences (B, 1, 85) such as: (a) a lack of

serious involvement in metric work and resistance to change by individuals, (b) a loss of uniformity of approach within the organization, (c) deferment of benefits from using metric units, and (d) extra time taken by the lagging staff members to convert to and from imperial units.

A good example of clear-cut policy on metric training, using a British-type approach, comes from New Zealand (B, 1, 16; B, 1, 43 and B, 1, 127); it states that all members of work-force whose livelihood depends on the use of metric measures should have metric training. All large firms or governmental bodies should internalize their training. In other organizations, staff on a supervisory level and above is entitled to metric training either on or off the job. Below supervisory level, metric training should be provided within the organization. Some of the free educational facilities available to the general public are also available to industry to provide courses or train company instructors. These facilities include technical institutes' courses, lecturer service, and the Industrial Training Service of the Labour Department.

3.8.2 Planning Metric Training Programs in Organizations

References dealing with planning and carrying out metric training programs are few but adequate. First, some general and idealistic statements about goals and desired aspects of training. According to the British Standard Institution, "the ultimate aim of re-training is that staff should think directly in metric system rather than by converting from the imperial system. This will probably not be fully achieved during formal training, though formal training should be designed to accelerate the familiarization process which will be completed afterwards. The best way to train the staff to think metric is by letting them work in a completely metric environment. Conversion charts and dual dimensioning should be used a little as possible after the early stages" (B, 1, 3). Complementing the above is a fragment from reference B, 1, 161: "The most important aspect of training for metrication is constant, stimulating exposure and subsequent practice."

We shall now review a planning procedure for metric training roughly conforming to that proposed by the British Local Government Training Board (B, 1, 97), but supplemented from other sources. This procedure assumes that a person (or a group) responsible for metric training in an organization has been chosen; he proceeds by following these activities:

Activity 1. Analyze training needs, i.e. determination of "who in your company has to be familiar with the metric system and to what extent" (B, 1, 72). There are several suggestions as to how to divide the staff into groups which need different levels and types of training; the following division was recommended in Australia for a large design/ construction organization (B, 1, 85):

a) executives/senior management
b) professional/technical staff
c) administrative, clerical, typing personnel
d) on-site operatives and tradesmen.

A more functional approach is found in reference B, 1, 97; each department's staff is broken into groups, the members of which should have a metric ability specified for that group (and for all those preceeding it):

group 1: name quantities in metric;
group 2: type or write in metric quantities;
group 3: calculate quantities in metric;
group 4: convert between imperial and metric;
group 5: explain relationship between imperial and metric.

Activity 2. Matching each one of these groups with one or more training methods (e.g. distribution of literature, on-the-job training group, in-house lectures, outside lectures, etc.) which fit their particular needs.

There is a reasonable agreement on what the above groups need. Several representative examples follow. For upper echelon executives: "a general session outlining objectives, opportunities, and management action necessary to bring about successful metric conversion" (B, 1, 85).

The same source suggests that administrative and clerical staff requires "a specific, task-oriented session catering to minimum requirements to perform satisfactorily in a metric work environment. Typists should be issued instruction leaflets setting out correct use of SI units and notation."

Suggestions for professional/technical staff are somewhat divergent. Some authors lean to "bare bones" information, backed up by literature: "We gave them a two-hour pep talk and that was all there was to it. Within two months they all preferred working and designing in the metric system" (B, 1, 72). Others are more comprehensive: the British Construction Industry Training Board (CITB) lists specific "learning texts and reference cards" to be given to professional staff members in addition to the courses which "deal with the cost implication of the changeover and cover basic metric knowledge, the broad and detailed implications of the changeover, dimensional coordination for the contractor and the organization of re-training" (B, 1, 57). Similarly, others propose that re-training a design staff should include the following type of information: the history of the metric system, reasons for going metric, clear exposition of the SI (especially the meaning of "coherent units"), dimensions and preferred units and an outline of company metrication plans (B, 1, 52). However, a letter from J. M. Guthrie of the British Department of Environment states: "Concerning training, there have been no specific training aids for Chartered (registered professional) Engineers in this country, it being left to the individual engineer to familiarize and convert himself."

Proposals for metric training of on-site operatives stress that these people should not be overtrained or confused with detailed descriptions of SI, if the understanding of only a few new units is necessary for them to carry out metric work "...In most cases a basic appreciation of linear measurement, and units for area, volume and mass (weight) is all that is required" (B, 1, 85). This sentiment is echoed in another British source: "...for most practical

purposes, most operations don't involve much measurement as such. They involve guaging (for necessity), and checking or measuring -- whether a tube is too small or will go through a ring or it won't -- it'll fill sloppily. It doesn't really matter what the units are. And secondly, as I said, the few units -- out of the whole SI that the people need in practice really only are a few -- 2, 3, 4 possibly 5 -- no more" (B, 2, 2). Site supervisors "who prefer to learn by organized courses" are exposed to metric units and symbols, calculating in decimals, reading metric drawings and ways to put metric across to others (B, 1, 57).

Literature on planning metric training and reports of actual experience are on the whole rather positive. As an example, take this Australian statement: "The change has novelty value, and experience has shown that measurements will be made with increased accuracy. Management should not underestimate the ability of staff and operatives to work in new units on the construction site" (B, 1, 85).

Activity 3. Setting up of a timetable for programs chosen above, i.e. deciding when and in which order the various groups should have completed their metric training. The most frequent advise found in literature is: don't train too early, do it "as late as possible.. not until your personnel have to work in metric. Advance exposure to basic metric names and associations will condition them for teaching the actual mechanics of the system. If the metric training starts before the employee needs it, some will have forgotten part of what they have learned by the time they have to apply it" (B, 1, 72).

Metric training of staff "should take place in the order in which they will be affected by the change. Management and technical staff (particularly designers and estimators) will come first, closely followed by clerical staff. Site staff will generally not be affected until later" (B, 1, 57).

Activity 4. Establishment of control procedures to follow the metric training effort down to individual staff

members. These include checking presence/absence in courses, performance in job exercises, performance on actual jobs, etc. There will be cases of early completion or delays, and of people whose special problems will be discovered during training.

A good number of practical procedures to be followed for the four activities outlined above, down to suggesting actual forms needed by the person administering the program, are given in reference B, 1, 97. At the beginning of this sub-section it was assumed that there was a person (or a group) responsible for metric training in an organization. The literature yielded some discussions concerning the choice of persons in charge of the entire metrication program. For example: "someone with authority should be placed in charge of the metrication program in your company. It certainly should not be someone who is sidetracked or about to retire. The person selected should be from or made a part of, the management group and should plan on being with you for a long time...He should select a person to head up the necessary metric education activities within your company. This person should...not be one who talks down to people, or puts himself on a pedestal to show how much he knows. You may wish to recruit someone...who is used to working with people...He must thoroughly believe in the necessity of converting to metrics and have the confidence of your personnel. Negative attitudes are taboo. If possible find a man who is "bi-lingual" as far as the metric and English systems of measure are concerned...(be sure he is using SI metric and not the old system)..." (B, 1, 72).

Finally the literature contains lists of metric training media. These are somewhat different depending on the country they come from. Typically, these lists include educational and reference publications, visual aids, (posters, wall-charts, displays and cut-outs), formal lectures, informal talks, internal advisory service, etc. For a good example see (B, 1, 85).

3.8.3 Experience With Metric Training

There are several references to actual experience with metric training: some of these refer to a particular company's experience, others are averaged-out reports, yet others are personal accounts.

Ford Motor Company (Dearborn, Michigan) reported that about 80,000 of their workers will have to be trained, the programs ranging from 1-hour training periods for administrative and clerical workers to 48 hour training programs for scientists, engineers and skilled workers. Total cost is about $16 million, i.e. about $200 per worker; 95% of this amount goes for wages paid during hours spent in (nonproductive) training. To gain a perspective on this number, total cost of Ford's metrication is estimated at 4% of a years gross sales (15 billion in 1969). Thus training represents about 2.5 percent of the total metrication cost (B, 1, 64).

Another source (B, 1, 147) reports a rather unique situation: union leaders of an American company took initiative and organized external training sessions for their members, when it became clear that the company did not intend to organize an internal program. Contact was established with an extension service of a local university which provided the lecturer, and a local area technical college gave additional support, so that total cost was only $2 per person. Employees who took the course were older and apprehensive of the change to metric, but the results were satisfactory. Supervisors from the same company, who were not union members, demanded that the company provide a similar arrangement for them. They succeeded. Remarks of the union man who took the original initiative are well worth repeating: "The guys in the shop are nervous about things they don't understand. Help them to understand and they are willing to move ahead. Tailor the course to the requirements of the group. Don't overburden them at first. Those that want or need additional information will ask for it. Use your local resources, such as the universities and vocational institutes. Give

the men and women plenty of material that they can take back into the shop with them and use on the job. Don't worry them with tests, the motivation is there and the true test is the application of the knowledge applied directly on the job"(B, 1, 147).

British literature on training gives a lot of credit to the Construction Industry Training Board (CITB), and the technical colleges. The former put out training manuals and set out the program that the construction industry was supposed to follow. Technical colleges incorporated these into their regular programs (for new graduates), and they also mounted ad hoc courses to meet the needs of local industry. Minimum class size was about 12-15 people (B, 2, 2). There are examples where highway and bridges department of a local authority, in cooperation with a local technical college, organized a traveling metric training program, which moved among actual job-sites. The whole thing was a roaring success and is widely imitated. They spent approximately half-day in a classroom, and another half-day on the job, which proved sufficient; "...this is important because often people oversell the training aspect, they think it requires some basic and fundamental reeducation and it doesn't, in practice. It means a very definite change in a small number of actions" (B, 2, 2). The same source cites experience of the British Aircraft Corporation which was building the Jaguar with the French, and whose workers converted within three days. It is stressed again that "it's very easy to oversell the training, especially for those who are in the training industry, who might naturally look for outlets for their wares" (B, 2, 2). Yet another warning in this matter states: "Many educators will be standing in line for grants to develop educational programs for extensively indoctrinating the general public, not only concerning the use of the metric system, but with its history, political and social implications, etc. Many schools will ask the taxpayers for funds to provide instant textbook changes. It is unlikely that many of these fund request proposals will be from those who have ever experienced a metric/English or vice versa, measurement conversion..." (B, 1, 72).

There is a variety of shorter statements related to metric training programs. Large British construction companies use the CITB course materials and internal lecturers for one to two days internal seminars (B, 1, 155). Smaller firms send some of their key personnel outside the firm to be trained and then come back and pass the knowledge down the line. Yet other firms bring lecturers from outside (B, 2, 2).

Construction companies have found that "premature courses are a waste of time and money, and all recommend that the seminars should be held at the commencement of the (metric) contract. Success depends on the leadership of the agent...Resistance to change is directly proportional to age...a repeat of the seminar, one month after the original one, helps to cement their metric knowledge" (B, 1, 155).

Several statements cite difficulties in acquiring familiarity with the new British Standards at the supervisory and subprofessional levels and in drawing offices. See, for example, (B, 1, 96) and the letter from J. M. Guthrie, Department of the Environment (A, 2, 39).

3.8.4 Personal Reactions to Metric Training Programs

Finally, a kaleidoscope of personal reactions to training programs and first experiences working with the new system in offices and on site follows:

Quite a few are positive without qualifications: "We have been extremely encouraged by the speed and enthusiasm with which the (design) staff have taken to working in metric" (B, 1, 62). "Most local authority designers have been pleasantly surprised at the ease with which site personnel at all levels have adapted to the use of metric measure" (B, 1, 8). "I was pleasantly surprised with the labor. How quickly top notch laborers were not having to use imperial measure...In fact this is my first job in a county that is metric...We went to metric completely and we found absolutely no problems. In fact it was a pleasure. We haven't had any mistakes to our knowledge in the field

from construction sites over the misreading of units. The philosophy behind the SI may be a big scientific bore but it hasn't presented us with any problems. In fact we had little 'bit of fun' books, they are crude things, handed out to every engineer. That's really all you need...People have been utterly fascinated with things like this. They get all what they call publicity with metrication at the time..." (B, 2, 11).

Some statements are moderate: "No serious difficulties have been reported" in the cement and concrete industry (B, 1, 120). Some others are interesting when considered in pairs: "I was amazed at how fast the Irish parties (were) quite happily talking about mm or 37.5 mm. Setting up is a pleasure..." (B, 2, 11). "A cement job where we had a lot of problems, we had a lot of Irish lads which hadn't seen metric...The men just did not want to know..."(B, 2, 12). Clearly the Irish labor force is not unified on metrication.

There are roughly as many difficulties described; these are usually rather specific: "The difficulty has been for the construction engineer (not for the design engineer) because in highway engineering actually we know what metre or a cubic metre is -- no real difficulty. In construction engineering you have this fundamental change to N (newtons) and you have some very strange stress arrangements for which you have no feel." (B, 2, 11). "...(initial stage) was a headache. I personally think that...the greatest problem of all was the calculation size...we found that it took most designers probably a good 3 to 6 months to really get used to the SI...it slowed them right down. When they designed a bridge in metric for the first time it was taking them perhaps 3 times as long than what they usually did in imperial. Even then they used to go home and slap their heads and didn't sleep at night and came back the next morning and said well is that unit right...(however) one bridge design was sufficient to enable them to become converted to the metric system" (B, 2, 11). "...(first metric job) was quite difficult. We were having materials delivered in cubic yards and we were having materials delivered in tons...we had to convert this...it takes some getting used

to mentally. To look at a thing and say well that is so many cubic metres...There muxt be a percentage of (workers) who even now aren't too happy with the metric system... and...one or two...not happy with decimal coinage" (B, 2, 12). These statements agree well with the prediction by Edwards (B, 1, 39) that "unquestionably the most difficult problem is appreciating the new mental images of size and recognition of whether the results of any calculation is sensible or obviously incorrect."

A frequent topic of discussion is difficulties encountered by older workers: "even where companies have metricated the older man still worked it out in inch terms and then did a conversion..." (B, 2, 7). "...older people having to do a lot of homework...(with) a lot of pressure in other work generally, and this sort of added load of metrication is something that we, most of us I think, would like a bit more time" (B, 2, 1). "SI units are a complete mystery to the old" (B, 2, 7). "Most people are frightened of the very idea and the belief...that there is such a lot to learn and a lot of complications to it, but in practice, when you start talking to people, I find it surprisingly reassuring how quickly they get acclimatized and can see the need for it to grow" (B, 2, 2).

3.9 Costs and Benefits of Highway Metrication

Predicted costs and benefits of highway metrication could be useful in three major ways:

(a) to find out whether overall benefits are higher than overall costs, i.e. to inform the decision-makers whether it is worthwhile to change over to the metric system;

(b) to choose between several alternative timetables for conversion that one which is expected to result in the largest net gain, and

(c) to find the distribution of costs and benefits among organizations and individuals, which would help in planning the conversion for these entities, and also substantiate their possible claims for support, etc.

Survey of various sources of information available for this study uncovered a number of discussions, mostly very brief, which address themselves directly or indirectly to the above aspects of costs and benefits. Before turning to specific issues, some general trends will be described.

There is little emphasis on the question whether overall benefits are higher than overall costs in the highway field. It is felt that once the decision is made to convert on the national level, highway metrication will follow suit, and overall figures in this particular field would be of little importance (B, 2, 2). Highway metrication has consequences in several different areas (e.g. governmental agencies, private construction industry, individual highway users, etc.) which are influenced by metrication in some other fields as well; it would be impossible to isolate cost/benefits effects on, say, construction industry attributable solely to highway metrication.

On the other hand, there are implications that the highway field would be neither a determined leader nor an opponent of a national drive for metrication. This sentiment can be illustrated by the statement of the Institute of Traffic Engineers (B, 1, 108): "The increased use of the metric system is desirable but not necessary. In traffic

engineering there does not appear to be any great advantage to changing to the metric system but for the sake of international standardization and wider acceptance as a common language for the expression of scientific and technical data, planned metrication is acceptable and is to be encouraged."

One of the most frequent topics is difficulties of both prediction and post-facto estimation of costs and benefits. Reasons are diverse: (a) the elusive nature of some cost/benefit items; (b) the impossibility of expressing some items in monetary terms; (c) costs of metrication are tied up with costs of other changes and it would be extremely difficult to separate them (a specific case of this is listed under (g) below); (d) costs and benefits are not directly comparable: costs are incurred mainly in the transition period, while some benefits do not even begin before transition period is over (B, 1, 79); (e) some benefits are made possible by metrication, but they require separate action, e.g. metrication creates opportunity for product rationalization in the construction industry but does not cause it (B, 1, 84); (f) the level of costs/benefits depends on the timetable adopted; if a sudden and radical change is made, the costs would be high, as well as in the case of prolonged, unplanned change; phased introduction of metric equipment might reduce some costs to zero, but it is not always possible to wait for the right moment, as the timetable of any one firm depends on timetables of many other firms who are its buyers and suppliers. Both premature and delayed metrication have serious cost consequences (B, 1, 96 and B, 1, 120); (g) in a period characterized by high inflation, it would be next to impossible to separate additional joint costs of inflation <u>and</u> metrication (B, 1, 8); (h) due to the confidential nature of cost information, very few firms are willing to be specific, even for those items where some precision is possible; (i) data from different firms are not comparable, being based on vastly different assumptions and criteria (B, 1, 96 and B, 1, 120). As an illustration, some estimates of overall costs of metrication in the U.S.A. ranged from $100 million to $200 billion (B, 1, 159); overall cost of metrication in India

were estimated to be about $25.6 million in 1964 (B, 1, 159). The British made some attempts to get cost estimates from different organizations: their answers ranged from "almost nothing to the most fantastic sums" (B, 2, 7). On the whole, British attitude appears to be that aggregate cost estimates are "futile exercise" (B, 1, 12). One company reported that the decision not to finance expensive research into costs of metrication was their first substantial saving (B, 1, 46).

On the other hand, there seems to be a reasonable agreement among the British writers that costs of metrication in the highway field have been by no means excessive. It is felt that the length of the transition period allowed people to phase metrication into their normal obsolescence and modernization schedule; for example see (B, 1, 46), (B, 2, 7) and, for similar thoughts on this side of the Atlantic, see the letter from E. Baugh, the General Motors Corporation (A, 5, 1).

3.9.1 Benefits

Before discussing benefits of highway metrication in three different areas (design, construction and operation), it should be said that many discussions in the literature start by outlining several classes of expected benefits of metrication in general, which are also applicable to highway metrication. For example (B, 1, 83), Australia expects to benefit from metric conversion through: (a) rationalization of standards; (b) gain in efficiency; and (c) an improved position in the world trade markets. It is expected that the permanent gain in efficiency would more than offset the one-time conversion costs. To amplify on the type of benefit listed under (c) above, here is a quote from an American article: "The language of international standards is metric. If we wish to get the rest of the world to adopt our superior engineering, manufacturing and quality standards, we had better express them in metric measuring language instead of our antiquated English system...More than 80% of approximately 20,000 (international) standards that are expected to be set within the next 10 years are still up in the air...If we in this country are not getting

more involved with international standard activities there is a chance we will be squeezed out. This could have a very unfavorable effect on our international trade balance" (B, 1, 72).

a. Benefits in Design

Design activities in which calculations play a major part will be simplified and speeded up by introduction of the SI. It is reported that "calculations can be carried out up to six times faster in SI than in the present non-coherent system" (B, 1, 161), which should significantly lower design costs. Overall level of comprehension of mechanical problems will be enhanced by separation of mass and force, as discussed in the section 3.2 of this report. The major reason that calculations in the Imperial system are so cumbersome is the proliferation of units and non-coherence of the system, which requires numerous conversions. Reference B, 1, 38 describes some of these conversions and states: "It is scarcely credible that designers should be going through these antics day in, day out, and in fact it is not really true. What happens is that manipulations of this kind which arise at all frequently are condensed into simple formulae or replaced by tables or charts, and the designer takes advantage of them to save himself a great deal of time. Some of these short-cut procedures can be found in handbooks, some are developed by individual designers for their own use or that of their colleagues. Frequently these formulae, etc., involve a variety of ill-assorted units, part metric, part Imperial, and includes numbers whose origin may be very obscure. The snag about this practice is that the designer forgets what he is really doing, or never even succeeds in understanding it; he just follows blindly the instructions provided with the formula, with the result that he gets into difficulties whenever he encounters something off the beaten track. This habit of producing tables and condensed formulae is so ingrained that well-intentioned efforts are now being made in some quarters to produce them in terms of SI units, overlooking the fact that the calculations they represent are utterly simple or even non-existent (in the SI). It should not be thought

for a moment that the proponents of the SI are academic purists who want designers to do extra arithmetic just to demonstrate their grasp of the subject. SI is essentially a practical system which has so great a simplifying effect as to render most short-cut procedures unnecessary." The same reference (B, 1, 38) describes an attempt to estimate time saved by an average designer through avoidance of unit conversion and the associated difficulties, which is made possible by adoption of SI. Different branches of engineering involved showed widely different times, the highest score being in the fluid-flow calculations. It was estimated that civil engineers (in this particular instance) waste about 4% of their calculation time on unit conversions; average calculation time per man-day was estimated to be about 40 minutes.

Another source states that "an unexpected saving has emerged in mechanical design draughting time where working in millimetres has proved appreciably quicker after one to two weeks than the life long practice in Imperial measure" (B, 1, 46).

b. Benefits in Construction

Transition from the Imperial system of units to the SI provides an opportunity to develop "a rationalized system of metric controlling dimensions linked to the dimensional coordination of building components" (B, 1, 50). As stated before, these benefits will actually accrue only if the concerned industry, professional organizations and governmental institutions act in unison to make use of this opportunity. Metrication does not bring dimensional coordination about by itself. Potential benefits stemming from dimensional coordination can be subdivided into (B, 1, 82):

(a) simplification of design, project documentation, surveying and site activities, ordering, manufacture and transportation of materials;

(b) reduction of component variety by discouraging the non-standard sizes; corresponding improvement in production economics through longer production runs; and product

improvements by spreading research and development funds over a smaller product range;

(c) the reduction or avoidance of waste of labor and materials due to cutting and fitting on site, and the reduced need for site labor .

There are several discussions of a trend in the construction industry "to move away from the concept of site operations being all craft based" (B, 1, 50), towards more off-site manufacture and prefabrication of components and assemblies. This situation is more important in construction of buildings than in the highway construction.

The literature also contains several references to actual experience with this type of benefits. Reduction in variety of fasteners, when dimensionally coordinated metric fasteners were adopted, was reported to be about 80 percent in South Africa (B, 1, 5). British Ford reported a drop in their parts list from 40,000 to 10,000 parts, a saving of 2.5 million pounds per annum (B, 1, 112). British Railways report that 39 Imperial sizes of bolts now in use will be covered by 7 metric sizes (B, 1, 46). On the other hand, there are some sceptical voices as well: "Benefits of metrication have, up to now (1971), been rather disappointing. Rationalization has not been as well defined, nor as widely applied, as one could wish. Company standards have been improved to some extent, but the opportunity has been wasted to a large degree. The lead should have been taken earlier and much more decisively by bodies such as the Metrication Board. It may not occur again for many decades" (B, 1, 46).

c. Benefits to Highway Operations

Highway metrication in the U.S.A. will have a positive influence on development of uniform international traffic control devices (B, 1, 108).

3.9.2 Costs of Highway Metrication

Discussions of costs caused by highway metrication are

rather infrequent in literature. Brief discussions usually identify various classes of costs; only occasionally there is an estimate on a particular item. Even reports on progress of metrication in Great Britain fail to quote costs actually experienced, for reasons outlined in the beginning of this section.

a. Costs in Highway Design

Classes of costs in highway design which would increase during the process of metrication are roughly the following: costs of revising manuals, standards and maps and cost records; costs of purchasing metric design tools; costs incurred to retrain employees; costs both to individuals and organizations of (temporary or permanent) loss of efficiency during the transition period.

Even though some of these costs should be easy to estimate, such estimates were not found. There are, however, some illustrative remarks, such as this one (B, 1, 62): "The cost to the office of changing to metric is not identifiable other than the time of the associate dealing with it. The whole of our standard documentation and specification has been revised, but this is in any case carried out at regular intervals. There must be some extra time taken by staff at the beginning, but usually they have proved so keen to become proficient that intial delays have been compensated by greater productivity later on. By making a fairly rapid change in the office, it is a one-off operation. If we had changed at a slower rate, there would have been greater overlapping of Imperial with metric and...more waste."

Some other statements (B, 1, 36) concern the amount of extra checking of calculations, especially in surveying, in the period of familiarization: "Extra checking...must add to costs, but there can never be too many checks and the amount of rechecking varies from job to job anyway, so it is not possible to say how much that cost is." The same source discusses costs of modifying computer programs used in design: "the cost of changing was not light, but looked upon as a once-and-for-all change it can be written off over

a period as a part of program maintenance."

Among the infrequent cost data found in the literature, there is a mention of some metrication costs to design (B, 1, 154): for the Surrey County (located south of London, population 1 million on about 400,000 acres and with 1,100 miles of directly maintained roads) overall costs of metrication for the drawing office and survey equipment, office and laboratory equipment are about 2,000 pounds (in 1965).

Costs of training are discussed in section 3.8 and loss of efficiency during the transition period is discussed in the following sub-sections.

b. Costs in Highway Construction

There are two sources of costs in highway construction: (a) The adoption of metric design standards causes some dimensions to increase; e.g. design speed of 120 kilometres per hour is more than the Imperial design speed of 70 mph (previously used in Great Britain) converted exactly and thus those roads whose vertical and horizontal curves are based on minimum design criteria (such as high-capacity inter-city network) will experience increased costs, (b) increased costs in the construction industry as reflected in bids submitted to highway authorities.

Some British sources (B, 1, 154) discuss the first type of costs mentioned above; the conclusion is that "the effect on rural and urban motorways is not likely to be appreciable since they are seldom designed to the minimum design criteria. But the cost of rural trunk and principal road earthworks, where 120 km/h is adopted and where vertical curves are likely to have a higher percentage designed at minimum desirable radius, is likely to be about 3 percent more..." On the other hand, some other British sources (B, 2, 1) deny that there is any increase in construction cost due to metrication of standards.

The second type of costs is discussed with a lack of

figures similar to the above. Costs mentioned under this type are due to: metrication of tools and measuring equipment, increased inventory in the transition period ("dual stocks"), costs of training employees and loss of efficiency, both temporary and permanent, during the training stage.

Some general British statements concerning this type of costs are worth repeating. "It is impossible to say whether or not the cost of construction has so far been affected by metrication. There is no direct evidence to indicate that it has but an objective view is obscured by the general inflation which the industry is experiencing during this period when early metric tenders are being received...One encouraging thing is that there has not been the anticipated wild increase in costs arising from the possibility that at each stage of the production of tenders an increment might be added for uncertainty. It was thought that if quantity surveyor's assistants, quantity surveyor's partners, contractor's estimators and directors of contracting firms progressively eased, weighted, tilted or added...to their assessments for lack of information or knowledge, the results would have amounted to considerable escalation. This is not detectable in the metric tenders received to date (1971). It is more important than ever to keep one's ear to the ground...the accurate forecasting of the lowest tender is still a surveyor's (and contractor's) primary aim." (B, 1, 36)

Another British source (B, 1, 8) states: "It is notoriously difficult to identify the precise cause of fluctuating costs especially when costs are rising rapidly for many different reasons. In England and Wales there is certainly no evidence from the general run of tenders in the public sector to support views that metrication is contributing substantially to rising costs even in the short term. Many schemes designed in metric have attracted tenders within the appropriate cost limits at the same time as many schemes designed in imperial dimensions exceed the cost limits. If metrication has marginally increased building costs overall, it is certainly not possible to

distinguish a differential effect between metric and imperial schemes."

Some figures were found which estimate the total cost of metrication to engineering firms or similar enterprises. While these figures cannot be used to predict what will happen elsewhere, they are of interest as illustrations of the order of magnitude of total costs. All of the following data on overall costs of metrication are from Great Britain, Unless otherwise stated. "A firm with an annual turnover of 450 million pounds expects the gross costs spread over a period of seven years to be in the region of 1.4 million pounds, or approximately 0.04 percent of annual turnover. Another major firm with an annual turnover of more than 325 million pounds expects the gross costs of a very comprehensive change to be about 1 million pounds. Even if spent in one year, this represents 0.3 percent of turnover" (B, 1, 96). Some smaller companies have reported costs in the range of 0.5 to 2 percent of annual turnover (B, 1, 10 and B, 1, 96). Note that all these costs are gross (i.e. benefits were not subtracted); the same sources indicated some positive results as well. Yet another source (B, 1, 46) reports that "an average of 15 large and small companies indicates a figure of 32 pounds per employee or 1.75% of annual turnover." It is interesting to note that larger firms' cost estimates tend to be relatively lower. At least one detailed report was found (B, 1, 78): the costs of a three-year transition were about 50,000 pounds for a British toolmaking firm employing 250 people, with an annual turnover of 1 million pounds. This is about 1.7 percent of annual turnover, or 185 pounds per employee. These firms include the time value of money. Additional interesting points are that the firm reimbursed all employees for replacing personal imperial equipment used on the job (as long as they never brought it to work afterwards). Their inventory holdings were 50% higher during the transition period, but fell below premetrication level afterwards, due to dimensional coordination.

It might be worthwhile to point out that these costs aren't anywhere near the nightmarish heights sometimes

found in the U.S.A. predictions. Actually, there seems to be reasonable agreement in Britain that net costs of metrication have been modest (B, 2, 7). In view of some current discussions in the U.S.A. about who is going to pay for costs of metrication, it is interesting to read that "the decision not to subsidize metrication resulted sometimes in ingenious methods to keep conversion costs to a minimum" (B, 1, 138). This is in step with "sink or swim" approach to metrication costs used in South Africa, while Australian policy on the matter is that no special provision will be made "to compensate for the costs of the change, since the long-term economic benefits are expected to be greater than the inital outlay. Costs must be borne where they fall, although ultimately they will be borne by the community as a whole" (B, 1, 82).

In connection with the above topic, there are several discussions in literature concerning costs of replacing personal tools which employees use on the job, and costs due to temporary or permanent loss of efficiency during the transition, the latter applicable to older workers. When asked about these issues, a British official answered that he "can't see that it's going to make a great deal of difference to trade unions themselves or their tools...construction industry has...a minimum amount of (affected) tools...What is a metric spinel, what is a metric screw driver...what's a metric saw, even chisels?" (B, 2, 1) On the other hand, an elderly British road technician said: "The young technicians...they just talk in Imperial units and they talk about your concrete at 35 newtons and they know exactly what they mean but when somebody talks to me at 35 newtons I have to think and think, you know?" (B, 2 3). Some sources in the U.S.A. report similar sentiments: "Labor unions are concerned about possible costs to their members for new tools and also for retraining. They suggested that these expenses should be borne by employers. Employers did indeed, view retraining and tool replacement as major cost items in their own estimates. On the other hand, some craftsmen are self-employed and might have to spend up to several hundred dollars for new tools as the nation changes to metric -- regardless of whether there is

a national program. Some labor leaders are more deeply concerned about a more subtle cost, which can be termed 'loss of experience'. Take the automobile mechanic who, after years on the job, instinctively reaches for the right wrench to loosen a bolt. When working for the first time, or even the tenth time, on a metric engine, he cannot rely on his instincts. (This problem has already arisen owing to the current increased use of metric units in the automobile industry). The mechanic unfamiliar with metric tools works slightly more slowly, less surely, and is therefore not quite so productive for some time. If he is a senior craftsman, he may even be at some disadvantage with respect to a metrically trained newcomer" (B, 1, 64).

Finally one more type of costs should be mentioned here. It concerns the firms which delay metricating their products, needed (for example) by the construction industry, hoping to profit from the decreased supply market of Imperial products. If many firms do that, the whole process of metrication is slowed down, and victims of this are those firms who fulfilled their promises and metricated at an early stage. There are some strong statements about this and calls for correction of the situation "so that staying imperial will not pay" (B, 1, 46).

c. <u>Costs in Highway Operations</u>

The major costs in highway operations will be change in traffic signs, those giving speed limits and those bearing distance information. The former will cause higher costs as they have to be changed in a short period. Even though the total number of signs is not given, it is of interest to quote the original British estimate of 2 million pounds for change of all road signs, which by now (1974) should probably be doubled because of inflation (B, 2, 1). The British have postponed changing the signs because of the magnitude of immediate expenses "although, in truth such road signs are being replaced all the time and in need of repair; there must be at least that much (2 to 2½ million pounds) spent anyway on road signs annually as a matter of course" (B, 2, 2).

Some U.S. sources contain references to costs of changing traffic signs. For example, the State of Kentucky is cited to spend ¼ to ½ million dollars for yearly maintenance and replacement of signs, but they do not have an inventory of signs and therefore cannot estimate the cost of metrication (B, 1, 99). In connection with sign changes, the same source notes that signs are under different jurisdictions, local, county, state, etc. A change in all pertinent ordinances would be required. Also, the spacing of signs is regular (1 mile) and these are sometimes used as references for location of accidents.

Another U.S. source (B, 1, 116) offers approximate costs of international speed signs; these are costs of material only and do not include labor. For lacquered signs, costs range from \$1.14 to \$3.37 per sign (depending on size, which in turn depends on whether the road is residential, urban or expressway). For reflectorized signs the range is \$2.66 to \$10.30 per sign. The date of this brochure is 1972.

3.10 Miscellaneous

This section will review some topics which were infrequently discussed in the literature, but which appear important enough to be included here; these are: legislative action connected with highway metrication, role of government in some critical stages of metrication and management of metrication in an organization.

3.10.1 Legislative Action

All our information on this subject came from Great Britain. There are approximately three types of legislative changes which the British are considering: (a) changing laws which require use of imperial units to allow metric units as well, (b) supplementing laws, which quote only imperial units, with a set of corresponding metric units so that both can be used, and (c) replacing imperial units in some laws by metric units and requiring that only the latter be used.

While the first two types of legislative changes are relatively uncomplicated in that they can be achieved by existing power to amend regulations or by subordinate legislation which is still in accordance with the present Act, perhaps using the so-called "blanket legislation" [see the letter (A, 2, 39) from J.M. Guthrie, Department of Environment], the third type can only be achieved by specific amending Acts (B, 1, 106). "Soft" conversion can be covered by the first two types of changes, but the "hard" conversion cannot. A simple example would be conversion of one yard. If 1 yard is specified in an existing law, "soft" conversion would amend the law in that it would add a translation of 1 yard into metric (i.e. 0.9144 metre) and either number could be used. In some cases it would be desired to replace 1 yard by 1 metre, and use only the latter; this would require an amending Act. Acts which require an amending Act to allow metrication are impediments to metrication, as it is not so easy to adopt them. For example, the Weights and Measures Act of 1963 (Great Britain) specifies that the power it gives to would be amenders shall not be used "so as to cause the exclusion from use for trade of imperial in favor of metric units" (B, 1, 106). However, two Orders under the same Act were enough to allow use of cubic metre in sale of some construction materials (sand, aggregates, ready mixed cement mortar, etc.) which was barred by the original Act.

Among the laws which specify imperial units and are barriers to metrication is the Road Traffic Regulations Act 1967; it specifies, for example, that the speed limit in built-up areas is to be 30 miles per hour which soft-converts to 48.28 kilometres per hour. However, Traffic Sign Regulations are also under the above act, but they can be changed by subordinate legislation

British literature also mentions a general metrication Bill which provides "for the authorization and definition of units of measurement which are to be used for all purposes...; for the removal of certain barriers to metrication in the existing legislation; and for constituting the Metrication Board as a statutory body" (B, 1, 53).

It is clear that metrication in some areas cannot proceed, even on a voluntary basis, before some legislative changes are made; in other areas, speed of metrication depends also on the legislative "push" which the government should provide. There are, however, some dangers involved here, as illustrated by this statement: "The Government has been encouraging everybody to go metric but they have been very slow themselves in metricating their legislation. A lot of people have complained about it, but...if they had pushed through all their metric legislation at an early stage you could have had a lot of people in trouble because they couldn't get their equipment recalibrated. But it is an essential part for the government to change its legislation into metric terms" (B, 2, 7).

Some examples of need for change in federal and state laws and regulations in highway transport were cited in our correspondence with American organizations. Typically, these are concerned with speedometers and odometers on motor vehicles, and regulations concerning vehicles' weights and dimensions (see letter from the General Motors Corporation, A, 5, 1).

3.10.2 Role of Government in Some Critical Stages of Metrication

A serious problem is encountered in connection with keeping up with the metrication timetable and the target dates that various segments of industry should comply with, so that problems of short supply and demand of metric components are minimized. Reaction of manufacturers to such target dates are to immediately question whether their part suppliers will have metric parts for them at the right moment, while the latter firms are hesitant not knowing whether there will be enough demand. This indecision loop lasts until the metric demand goes over 30% which is the "signal that they have to metricate entirely" (B, 2, 7). To get to those 30% and to break the circle you either need a pivotal firm, which enjoys a near monopoly, to exert a pressure on its suppliers and buyers, or the government has to exert this pressure as discussed below.

In connection with the above, special problems of small construction firms are mentioned in the literature (B, 1, 53). These firms have difficulties in dealing with both suppliers and manufacturers of their materials, as their share of the market is not large enough to influence either the metrication of manufacturers or willingness of suppliers to carry dual stocks. Similar difficulties were reported in personal communication with some small firms manufacturing construction equipment. In spite of the British steel industry's assurances to the contrary, the availability of metric sizes of steel sheets, etc. is mentioned as a major problem.

To combat the above difficulties and to ensure better cooperation within and between industry, British authors suggest several roles for the government:

- as the government is the single largest buyer of many industrial products, it could use its purchasing power to influence the suppliers to metricate their products in accordance with the pertinent timetable; as one person interviewed said, "he who pays the piper calls the tune" (B, 2, 11).
- some governmental departments in Great Britain "act as sponsors to the Government of particular industries and services"; they can "encourage their industries to establish or strengthen appropriate machinery to promote consultation and co-ordination of the metrication programmes of individual organizations and sectors" (B, 1, 53).
- the government could collect and make known to industry all information pertaining to demand for metric products in the near future; in Britain, this kind of demand forecasting was planned for each half-year (B, 1, 53).

3.10.3 Management of Metrication in an Organization

Management of metrication was discussed in the entire body of this review. This section reviews a few important ideas which were not emphasized before.

The nature of metric change for individual organizations greatly varies, depending on the type of their productive

activities. For example, if a firm produces construction materials such as sand, chemicals, paint and such; metrication means mainly change in units of sale and dimension of packs. A firm is involved with bridge design, or other firms whose product changes, guidance has to be sought in the revised national standards. In Britain, the most critical changes are those for the semi-finished materials, particularly metallic materials, whose choice of ranges of preferred sizes was made by the British Standards Institution after lengthy consultations, also attempting to conform to international standards (B, 1, 53). In sum, there are organizations whose metrication is more or less an internal endeavor, and others who are dependent on external decisions concerning their supplies, dimensions of their product, and demand for their product.

We shall briefly survey some key issues which have to be considered in the internal aspects of metrication. It is suggested that "the best approach to metric conversion will be to consider it as a management function with technical overtones" (B, 1, 85). The same source lists some key decisions which have to be taken by the management:

- how to go about the change
- when to start preparations
- who should control the change
- what areas, systems, people and operations are affected
- what back-up data and references are essential
- how and when to condition and train people
- when should documentation, production, or construction in metric be commenced
- what capital investment is desirable, necessary or possible, and how is it best allocated
- what restriction in the product range is practicable
- how can the existence of two systems (metric and imperial) for some time be best coped with.
- how to adjust for changes in purchasing policies for materials and components, and in stocking policy and control
- how should metric products be marketed
- is there scope to consolidate skills or activities, etc.

One of the most important decisions is to assign responsibility for metrication: "Management should appoint a person, a number of people, or a committee to appraise all factors involved in the change; how these will affect the performance of the organization; and how the total program can be organized and controlled. <u>It is best to allocate overall responsibility for the control of all metric activities to one person who reports directly to the chief executive</u>" (B, 1, 85). This man, called metrication officer or metrication chief, (or, in case of a group: metrication panel) should "coordinate key interests such as the design office, purchasing department, training division and shop floor; and provide a focal point for the staff to discuss the change and keep in touch with developments" (B, 1, 3). For managerial and human qualities wanted of this man, see sub-section 3.8.2.

Task 2

Summarization of ODOT's Five Phase Work Program

Chapter 1 - Introduction

Task 2 of the Metric Research Project involves the Summarization and Evaluation of the Ohio Department of Transportation's (ODOT) Metric Work Program. Five phases are included in ODOT's Program and are enumerated as follows:

- Phase 1, Design, involves the actual design of two highway projects using the metric system (in particular, The "International System of Units" or as commonly known, the "SI") of measurement throughout the development of contract plans.

- Phase 2, Construction, involves the actual construction of the two projects designed under Phase 1. This phase will require the Contractor to use the metric plans and will include layout, inspection, testing and documentation - all in metric units.

- Phase 3, Public Use and Adaptation, consists of the erection of 33 dual distance signs on Ohio's Interstate Highway System. These signs give distances to major cities and intersections both in kilometres and miles and they are intended to gradually acquaint the motorist with the metric unit "kilometre" and its relationship to the mile. Determination of motorist response to the metric informational signs is part of this effort.

- Phase 4, Public Information, involves the distribution of a metric information packet and periodic news releases concerning Ohio's metric projects. The packet relates the history and advantages of the metric system and offers simplified conversion tables showing the relationship between customary American and metric units.

- Phase 5, Public Reaction, involves the determination of the general public's attitude and reaction to the metric signs erected under Phase 3 and to the metric public information distributed under Phase 4. This phase will inventory their comments, recommendations and opinions and will solicit their suggestions for future changes.

Much of the work involved in this task was summarized and discussed in this research project's "Interim Report" dated August 1974. The cut-off date for input information for the interim report was July 15, 1974. The following chapters will include all pertinent information regarding this task, however, the Interim Report appendixes related to the design phase have not been reproduced. For more detailed information concerning this task from the start of ODOT's metric work program to July 15, 1974 please refer to the "Interim Report" which is available through the Federal Highway Administration in Washington, D. C.

Chapter 2 - Phase 1. Design of Metric Highway Projects

2.1 Introduction

The introduction to Task 2 stated that the design phase of Ohio's metric work program included two highway projects. That statement is essentially true since only two projects have been included as part of the design and construction phases of the "Highway Metrication" Research Project. However, the Ohio Department of Transportation has actually been involved in three metric highway projects. These projects have been designated as follows:

- Metric Project No. 1 (LIC-161-0.00).

  The analysis of the design of this project has not been specifically dealt with in this research project due to its simplicity. However, it will be discussed briefly in Section 2.2 to acquaint the readers with what was done.

- Metric Project No. 2 (HOC-93-0.14).

  The analysis of the design of this project is covered in detail in Section 2.3.

- Metric Project No. 3 (PER-188-03.84).

  The analysis of the design of this project is covered in detail in Section 2.4.

Note: See the Map of Ohio showing the locations of the three metric projects (Figure 7 in Chapter 4 of Task 2).

2.2 Metric Project No. 1 (LIC-161-0.00)

This project involved the resurfacing (with bituminous concrete) of 8.206 kilometres of State Route 161 in Licking County starting at the Franklin County line. This project was originally designed and calculated using customary American units. After a decision was made to change it to a metric project it was recalculated. Two decisions were made prior to recalculation of the quantities; the width chosen was 7.32 metres (24.0055 ft.) and the thickness was set at .025 metres (.984 inches). Stationing on the project was at 100 metre intervals with the first several stakes placed at 50 metres spacing. A metric (Celsius) asphalt concrete thermometer, furnished by O.D.O.T. Central Laboratory, was given to the project supervisor. Special conversion charts of customary American to metric units were given to all representatives. Project and plant inspectors were given additional training, lasting approximately one hour, on the metric system and in converting between the two systems. The general summary in the plans was presented in both metric and customary units. No problems, relating to the metric aspects of the project, were experienced during the design phase.

2.3 Metric Project No. 2 (HOC-93-0.14)

This project involves 1.698 kilometres of highway relocation and upgrading and includes a bridge. The project is located in Hocking County, which is part of ODOT District 10, about 17 miles south of Logan on State Route 93.

2.3.1 Methods Employed to Obtain Information

The various units within the Ohio Department of Transportation which were involved with the design of Metric Project 2, HOC-93-00.14, were:

- Transportation District 10
- Bureau of Bridges
- Bureau of Roadway Design
  - Design Development Section
  - Hydraulic Section
  - Geometric Section
  - Plan Review Section
  - Estimating Section

- Bureau of Transportation Technical Services
  Aerial Engineering Section

- Bureau of Research & Development
  Specifications

Each of these units provided information through one or more of the following methods: Written reports, personnel interviews, or review of correspondence. Additionally, the completed plans were reviewed by members of the Metric Research Team. Summaries of these interviews and selected plan sheets were included in the Appendixes of the "Interim Report".

2.3.2 Metrication of Surveying

The necessary equipment obtained for field surveying were a 3.6 m metric level rod, a 30 m metric drag chain, a 50 m metric box tape, and a 3 m metric pocket tape. This material was available from a Columbus supply house at approximately twice the cost of customary American equipment. Those interviewed indicated the quality of the material with regard to accuracy was in general as good as that normally used. However, there were some complaints concerning both the rod and drag chain.

The length of the rod made leveling on steep slopes a tedious chore especially if done with a lock level for less accurate measurements such as checking cross sections. When using a lock level, only even units of elevation are read. The rod thus had only three even units. It was indicated that in the future a longer rod, similar to a 25' rod, should be obtained. There was one feature of the rod that was superior to the present equipment, however. At one decimetre intervals the whole metre value is shown by an appropriate number of black dots. These are easily visible and eliminate the necessity of "raising for red" as with rods graduated in feet.

The drag chain was an "add-metre" type and the add-metre was a source of problems. The additional length, which had to be stretched out for accurate measurements, proved unwieldy. This was compounded by the fact that this metre was only graduated in decimetres except the last decimetre which was in centimetres. Therefore the chain had to be marked with a pencil and the last fraction of the metre

measured with the pocket tape. It was suggested that until finer graduated drag chains are available that the last measurement on a line could be taken with the box tape which is graduated to centimetres and millimetres.

Since electronic measuring devices are now all metric, this equipment area poses no problem. The Aerial Engineering Section does have one device that reads in both metric and customary American units. They felt that this would be an excellent aid during transition both by allowing surveyors to get accustomed to the metric system and as a double check of the data obtained. These instruments cost approximately $5000 each.

No effort was made to use grads in lieu of degrees, minutes and seconds as this would involve changing instruments which are by far the most expensive pieces involved in field surveying. It was noted that "only France" of all the metric countries had converted to the use of grads.

For aerial photography and photo development all present equipment is metric and will require no change.

For manuscript preparation "the AP/C coordinatograph is fitted with lead screws 1200 mm x 1400 mm...However, the advantages of an independent method which we use for grid layouts in English units makes use of a metal template with drilled 100 mm grid intersections an attractive alternative." This template was manufactured in Switzerland and obtained from a Philadelphia Supplier for $165 (1973 prices).

For contouring "tracing tables provided with the original Kelsh plotters were fitted with lead screws with a pitch of 1 mm/rev. and a fixed readout to 1/10 mm...Later tracing tables had lead screws in the English system and were provided with a variety of gears to read directly in ground units. This method is so attractive in engineering work that we elected to find a very close equivalent in ground units making use of the modern tables...While contouring was no problem reading cross-sections proved troublesome since suitable gears for digitizers (for horizontal distance from ℄) were unavailable...However we would prefer to obtain modern tracing tables with metric lead screws and a variety of gear sets to work directly in exact ground units." The obtaining of metric digitizer bars necessary for cross-sectioning may pose a problem, since the ones presently used were a prototype made by K & E and the personnel of Aerial Engineering were "not sure they were even made for metric units."

For field surveying all elevations were read to the centimetre except for the benchline where they were read to the nearest 2 millimetres. All horizontal measurements were taken to the nearest millimetre. For Aerial surveying and mapping the following scales were used:

Scale	Where Applied	Accuracy
1:100	cross-sections	read to 0.1 m
1:200	site plans	0.5 m contours
1:500	design maps	0.5 m contours
1:200	location maps	2.0 m contours

All measurements taken in field surveying are more accurate than those usually used except for pavement elevations while the contours used for aerial surveying are all less restrictive than those normally obtained for similar English scales. It was the opinion of Aerial Engineering that "greater accuracy for cross-sections should be specified."

Horizontal curve and spiral tables for centerline layout were prepared by computer using a degree of curvature based on a 100 m arc for 1 D_{cm}. The survey crews had no trouble with the use of these tables.

The major problem indicated in the metrication of surveying was the lack of a worldwide metric projection system for ground coordinates. "At this date no satisfactory replacement of the Ohio Plane Coordinate System for engineering surveys has been devised and accepted. A world wide system based on the Universal Transverse Mercator projection with 1,3 or 6 degree band has been suggested. There is a chance for confusion in using metric coordinates since the definition of equivalent English units has changed over the years. The (former) U.S. Coast & Geodetic Survey always based their surveys on metric measurement but the SI definition of 1 m = 25.4 mm (exact) rendered all the published data obsolete. It is believed that new SI coordinates will not be available until after a new general adjustment based on world wide satellite observations is made, perhaps by 1980. Until then extensive metric surveys are likely to extend the confusion."

Metric ICES "ROADS" programs for highway design were obtained from McDonald-Douglas by Aerial Engineering and Data Services. These compute geometry, plot cross sections and compute volumes in metric units. Only two small problems were indicated. The stationing used on the plan did not use the plus (+) common to American highway projects while the program still used this designation for stationing.

This is a minor problem and can be easily corrected once a method for metric stationing is agreed upon. The other problem will have to be corrected before any volume of metric work is done. Metric sized paper was used in the Calcomp plotter, and while the plotter plotted cross-sections properly it would not register properly for the succeeding cross-section necessitating an operator adjustment for each cross-section.

Other than previously mentioned problems with materials or conversion of soft-ware no particular difficulty was encountered in the actual work in the metric system. Field crews in District 10 were given a half hour orientation and then given the metric equipment to practice with for a few hours. They then started field work and after about a week had become fairly well accustomed to working in the metric system. The survey crew noted one problem. They were involved with other projects during this period, and each time they returned to the metric project a short period of readjustment was required. Accuracy of measurements and quality of field notes were in general as good as usual, but the crew did mention they were a bit more careful because they were working in a new system. It was the opinion of the survey crew that the physical work would still remain the same once they had become accustomed to working in the metric system and, therefore, no appreciable advantage in time saving could be accomplished by metrication in their area.

The flight design for aerial survey posed no problem whatsoever. The elevation was determined simply by multiplying 5 times the scale by the camera focal length. This was actually easier since the camera was calibrated in mm which eliminated conversion of units. Manuscript preparation proved just as easy as in English units once the metric template for grid layout was obtained. The Kelsh operators took more time than usual, but it was attributed to using the converted contours and lack of digitizer bars for cross-sectioning. It was believed that once metric tracing tables and horizontal digitizers are obtained there will be no appreciable difference in the work involved.

Use of the metric computer programs were actually easier due to the fact that the typical section in metric was all in one unit. This eliminated the need to convert inches to feet and slopes in inches/ft. to a dimensionless ratio. The general concensus of those involved in this area of work was that work in the metric system was much easier than they had first expected.

2.3.3 Metrication of Roadway and Bridge Design

The only metric design tools purchased by either District 10 or the Bureau of Bridges were scales and paper. The scales obtained by District 10 were ordered from a local (Marietta) dealer. Only one metric scale, a K&E @ $16.00, was in stock. Others had to be ordered and required a four week delivery time. Although less expensive, $5.00 each, the draftsman who used them indicated they were not as good a quality as the more expensive scales. The Bureau of Bridges had purchased two metric scales previously, so no attempt was made to purchase any at the time of the project. The scale used by the detailer was graduated its entire length, instead of just at one end, and he indicated that placing on the wrong marks could be a source of error. In general the engineers felt the scales were as accurate as needed for their work. The major complaints were the lack of variety of scales and number of scales available. A number of good quality metric scales with varied plan scales will be necessary before many more metric projects are designed.

The procurement of metric paper and linen was an even greater problem. The District finally designed the plan sheets on an A1 metric format and ordered linen. Delivery of the tracing cloth took an excessive amount of time and nearly delayed the production of the plans. The Bridge Bureau obtained paper from the district and manufactured linens by cutting down present stock to metric size and re-bordering. Since bridge plans are put on plain paper without any grids this proved to be the easier and cheaper alternative. Those who worked with the cross-section sheets felt the quality was good and the grid (heavy lines every 20 mm, light lines every 2 mm) was sufficient for the cross-section scale used. The detailer for the bridge design, however, indicated that the paper was smaller and didn't allow as many details per page.

Horizontal curve templates based on a 100 m definition of degree of curvature were not available. This did not pose a great problem as the project had only a few small horizontal curves. However, once a decision is reached on what horizontal curve definition will be used, they will be required before any volume of metric work is done.

It was noted during the discussions with Bridge Bureau personnel that electronic calculators are available that are

programmed with conversions from English to metric units. It was suggested that these might prove useful during transition, especially in converting tables, charts, formulas, etc.

The conversion of Design Policy and Design Aids probably added the most extra time to the metric project both when it was done and when it was not. Conversion of design aids took time, while designing time was increased if design aids were not converted. As this project was a rather simple job, Roadway Design policy and aids were changed very little.

Design speeds, recommended by the District, are shown below and vary little from present design speeds. No change was made in sight distance tables. It was noted by the geometrics reviewer that this would be no problem if it were to be done. The only question would be whether or not to change the height of observer and height of object to nominal metric. Conversion to the metric system does not affect vertical curve formulas at all, but it was recommended that lengths of curves be divisible by 20 metres.

MPH	Actual km/hr	Rounded km/hr
40	64.3720	65
50	80.4650	80
60	96.5580	95
70	112.6510	110

A definition of degree of curvature based on a 10 m arc was originally proposed but this was changed to 100 m definition after further study into the matter. Horizontal curve, spiral curve and superelevation tables were provided for this definition of curvature. Calculations were done by computer with no evident problems. Although these tables were not really necessary for the designer, they were needed for the draftsman and surveyors. It was later suggested that a 20 m definition of curvature could be used.

The concensus of opinion was that all geometric design aids could be revised rather easily by utilizing the computer. The only thing necessary beforehand would be decisions on what definition of degree of curve would be used, design speeds, etc.

Very little was done in converting hydraulic design charts and formulas to metric. The preliminary design section of the Bridge Bureau did all hydraulic calculations in

English units using standard design aids and converted the results to metric. For culvert and ditch design only the runoff equation used in culvert design (Bulletin 43, Ohio Department of Natural Resources) was revised with input and output in metric. However, U.S.G.S. maps used to calculate drainage area and main channel slopes are in English units; and, therefore, until these are revised, conversion of this input will be necessary to use the revised formula.

Neither culvert design charts, nomographs, nor the computer program for culvert design were revised. Those who worked on the design of ditches and culverts found conversion of units back and forth to use these tables to be the greatest hindrance in project design and indicated they should be converted before more jobs are done.

The typical sections used for the project had dimensions rounded "freely" to nominal metric and all cross slopes given in percentages. The only complaint regarding the use of nominal metric dimensions was about the ditch radius used, 7.25 metres. The ditch radius commonly used on this type of highway is 20 ft. which converts to 6.1 metres which rounded nicely to 6 metres. The geometric reviewer could see no reason to change policy when a nominal metric dimension conformed so closely. There was some concern that changing to nominal metric dimensions would create a problem for construction equipment, but this does not appear valid since the majority of the equipment does permit adjustment within reasonable limits.

The greatest amount of comment was generated by use of percentages for all cross slopes with comments ranging from favorable to highly unfavorable. Most of the favorable comments were based on the idea that it will be more uniform than the present system which uses such varied units as 3/16" per ft. pavement fall, 2:1 side slope, and 4% profile grade. The negative comments centered around it being a useless exercise on side slopes, for a dimensionless ratio is the same regardless of the system of measurement and the ratio is easier to plot on cross-sections. In general, those who worked with the percentages for cross slopes had little trouble once they became accustomed to that method but did have some problem visualizing slopes at first. One suggestion was made that instead of using percentages for slopes just use the grade itself (i.e. 0.015 in lieu of 1.5%).

No bridge design charts, standard drawings, or suggested details were revised to metric units, although detail design formulas were converted. The conversion of formulas proved no real problem except that the pile driving formulas had to be redone from scratch and could not be directly converted. All preliminary design calculations (type, size and location) were done in the English system and end results converted to metric. All detail design calculations were calculated in metric units using converted formulas that were available. The detail designer estimated that design calculations required about twice the time which could be expected using English units. The main reasons being necessity of conversion of design loads and suggested details to use metric formulas, and/or conversion back to use design charts in the English system. Those suggested details were then converted to nominal metric sizes where construction practices and materials would allow (e.g. pier footers and pier caps). However, those which require standard forms or materials (e.g. prestressed concrete beams and pier columns) were converted directly to equivalent metric sizes. Not being able to refer to metric standard drawings doubled the time necessary for preparation of the plans.

Although it was agreed that these aids would be necessary before any volume of metric work could be done, a general attitude of procrastination prevailed. The feeling being "wait until industry provides materials". A rough time estimate of 2 years was given for converting standards and suggested details. It was suggested that nominal metric dimensions be shown in parentheses on standard drawings and suggested details during transition from English to metric.

Roadway standard drawings pertinent to the project were revised by District 10 and included in the plan as construction drawings. All English dimensions were then removed from reduced negatives and these then enlarged to metric sized sheets. Metric dimensions were then added. Nominal dimensions were used where construction practices and materials would allow. No attempt was made to redraw to metric scale. This did not involve an excessive amount of time, as all revisions were determined by the District Design Engineer. The only negative comment concerning the standard drawing was voiced by one of the plan review engineers. He felt that maybe the dimensions were a little "too nominal" for an initial project and might cause construction problems.

Although necessary before any volume of metric work could be done, it was noted that revision of all of the Bureau of Roadway Design's 62 standard drawings would not be as simple as those revised for this one project. Whereas the revisions done by the District were one man decisions, any major revisions of standard drawings involve many individuals, all of whom may have different opinions. From conception to the time when a mutually satisfactory standard drawing is obtained, major revisions or new standards may take anywhere from 6 months to two years. Dual dimensions with nominal metric in parentheses are a possibility for transition; but some standard drawings would probably have to be redrawn, for there would not be room for added dimensions. As could be expected, concern was expressed over obtaining metric materials before revisions could be made.

Unit price estimates were prepared for roadway items by converting quantities back to English units, calculating item cost in English units, and then computing metric unit costs. Unit prices of bridge items were estimated using revised cost tables and calculated in metric units. Roadway items were estimated in the aforementioned manner because of the short period of time available to meet the job schedule. It was indicated that little difficulty would be faced by the estimating section of Roadway Design in converting to the metric system, because cost tables must be constantly revised anyway due to inflation. It would involve only one more revision to use metric units. However, until all projects designed in English units were processed, dual tables would be necessary.

All specifications pertinent to the project were revised in metric units, which involved approximately 50% of ODOT's specification book. However, a large part of those not revised were items that "are not commonly used." The work was coordinated by the Specifications section of the Bureau of Research and Development.

The basic criteria for revising the specifications was to use nominal metric values wherever possible without changing the intent of the specification or creating a burden on the contractor due to material or equipment complications. Therefore, some values were liberally rounded, while others were strictly converted. The A.S.T.M. publication on conversion, ASTM E380-72, was used as the principle guide. It proved quite helpful along with the fact that many A.S.T.M. specifications referred to in ODOT specifications are already given in metric units.

Although the actual conversion of numerical values and rounding posed little difficulty, there was considerable argument over what metric units were to be used. Basically most differences of opinion occurred between two groups, "SI purists" and "practicalists". The SI purists contended that conversion to metric is conversion to SI recommended metric units. Those units pertinent for the highway field being kilometres, metres, and millimetres for linear measurement; only squares and cubes of these for areal and volumetric measurement; kilograms for mass and newtons for force with a clear distinction between the two; and pascals (1 N/m^2) for stress and pressure. The practical argument was based primarily on two premises: "Why not make use of all metric units" and "Don't use units that people can't relate to." Regarding lineal measurement use of the centimetre was suggested, for "going from millimetres to metres in measurement is like going from a penny to a ten dollar bill." The use of the litre was suggested for liquid volumetric measure as a practical unit between the vastly different sized cubic millimetre and cubic metre. The separation of force and mass in highway work was most vehemently argued against by this group. The primary reasons being the "units are confusing" and there's no "practical advantage" in "multiplying both" action and reaction "forces by the force of gravity". It was suggested that pressure could be given in kg/cm^2 which is more "identifiable".

The units finally chosen were a compromise between the two differing points of view (See Section 2.4.5). The metre and the millimetre were chosen as the units of linear measurement, since the use of the centimetre would not solve one problem inherent in the metric system. There is no metric unit that is equivalent to the normal accuracy used in highway construction, one hundredth of a foot or an eighth of an inch. When dimensions are given to these two units a tolerance of one half the unit in either direction is generally assumed unless stated otherwise. The millimetre is about three times as restrictive, while the centimetre is about three times as lenient. It was indicated that for some items such as concrete and laying conduit accuracy to the centimetre might be allowable if this unit were used. Unless policy is changed for allowable accuracy some statement of tolerance on dimensions will have to be made when metric dimensions are used.

The litre was used as the unit of volume for liquid measurement, as the cubic metre did not work well for most

rates of application. The litre is also an easily identifiable metric unit. For volumetric measurements usually given in cubic yards, however, the cubic metre was an excellent replacement unit. Square metres proved a suitable replacement for square yards as an areal measure.

It was decided that clear separation of force and mass would be made, as this is an integral part of the metric system. Amounts of material would be expressed in the mass units kilograms or tonnes (1000 kg), while forces would be expressed in newtons ($1N = 1\ kg \cdot m/sec^2$). It was suggested that references and sample problems be made available to acquaint personnel to the application of mass and force in the metric system. The units of stress and pressure chosen were the N/m^2, KN/m^2, and MN/m^2 rather than the formal definition pascal, as these clearly express stress and pressure. Newtons per square centimetre was not used, since ASTM E380-72 recommends that prefixes not be used in denominators. It was noted that use of one unit lends itself well to comparison of allowable stresses and pressures unlike the present system of psi, ksi, psf, ksf, tons/ft^2, etc.

Although everyone agreed metric specifications would be necessary for metric jobs, the opinions on how the matter should be handled during transition varied greatly. Proposals for the completion of the revision ranged from "complete the revision immediately" to "add just those specifications necessary for each new metric job" (assuming there will be more before complete conversion occurs.) Basic recommendations for presentation of revised specifications included have "separate spec books" for each system; have dual dimensioned spec books with gradual transition where units would be given in the following transition order

*C.A.   C.A.(Metric)   Metric (C.A.)   Metric;

or keep the metric supplement until complete transition occurs and then just have one spec book, metric. Some concern was expressed that many of the metric revisions would themselves have to be revised when metric standard material and construction equipment became available.

Several changes were made in actual plan preparation. Most notable was that metric plan scales were used. Those suggested by District 10 for roadway plans are shown on the following page.

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*C.A. designates customary American

Plan	1:500
Vertical Profile	1:100
Horizontal Profile	1:500
Cross Section	1:100
Details	1:100

The draftsman who did the majority of work on the roadway plans suggested one improvement. Culvert details had the same scale for the vertical and horizontal dimensions. He suggested that allowing a larger scale in the vertical dimension would give more clarity to the drawing. Scales chosen for detail plans for the bridge were those most similar to the customary American ones normally used, with the exception that all vertical and horizontal scales were the same. The Bridge Bureau detailer had the same comment regarding dual scales as the draftsman in District 10. He also found that a table he constructed comparing American scales and similar metric scales (1/4"/ft. ≈ 1:40 etc.) was quite helpful in his work before he started to "think in the metric scales."

All dimensions on bridge detail plans were expressed in millimetres to avoid having to label units. This did produce quite a large number on long dimensions, which met with a great deal of disapproval. It was not until after the plans were drawn up that an alternative method for avoiding labeling was proposed. A method used on many metric plans to differentiate dimensions in metres and millimetres is the use of a decimal point. If a decimal point is shown the dimension is in metres; if not the dimension is in millimetres. This alternative was generally satisfactory to all who asked about it.

Profile elevations were plotted every 20 metres with 10 metre increments on vertical curves. Cross sections were plotted every 20 metres which closely approximates the 50 foot increments now used. The 20 metre stationing also simplified earthwork calculations.

The centerline distance designation chosen was completely different from that commonly used. It abandoned the use of the 100 unit station and instead appeared in what one engineer titled "meter point". It appeared as a large numeral in the kilometre place, a comma, a large numeral in the hectometre place, small numerals in the decimetre and metre place, a decimal point and then small numbers.(e.g.1,2$_{34.56}$). Two main reasons were given, "the plus does not belong in

the metric system" and that it differentiates this from a plan in customary American units. This brought many negative comments, the most practical being "you cannot type it" that way and "there were too many numbers to put on a stake" in survey work.

There was some hesitancy or doubtfulness expressed by some of those who worked on the job prior to starting; but in general this subsided once work began, and many found the work actually much easier than had been expected. In general, education of personnel working on the job was minimal. The Design Engineer in District 10 held a short meeting to explain the metric system, and the training officer distributed metric supplies. The technical specialist in the Bridge Bureau distributed some metric information. It was suggested that sample problems in both metric and English units be given to people to show the comparative ease of calculating in metric units. This was done by the District 10 Testing Engineer, and he was quite pleased with the results. The District Training Officer indicated this method had worked well with the public during demonstrations at county fairs. It was also suggested that a library of metric references be compiled for use by ODOT personnel. However, "on-the-job training" would still be the best way to "really get accustomed" to the system.

In general, no real difficulty was encountered in design calculations except for those instances noted before where conversion back and forth to use unrevised design aids was both time consuming and an added source of error. The only problem occured after calculations were made. A more careful check had to be made because designers were unfamiliar with the units and could not rely on experience to know if results of calculations were reasonable. Checkers and reviewers generally expressed the same opinion. The problem was to become familiar with the new units and "think metric" rather than trying to compare to the old system. No more errors occured in design calculations done entirely metric than normally would be expected.

As could be expected from using units which are based on multiples of ten, nearly all plan quantities were easier to calculate. The elimination of the odd conversions between inches, feet, and yards in quantity calculations was expressed as the greatest advantage in the design of a project.

There were no real difficulties encountered in the mechanics of converting what policy, specifications, and aids were revised. The major problem expressed by District personnel in this matter was finding what had to be converted, because the design policy and aids come in fragmented form rather than in one easily used manual.

Most complaints regarding the project centered around organization of the Central Office level. Work on the project was fairly well organized at the district level Meetings were held and attended by district design, construction, testing and right-of-way personnel. Discussion covered primarily what would be done, how it would be done and who would do it. All other offices indicated that they were kept well informed during actual design of the project. The Roadway Design Area Engineer for District 10 also worked more with the district in making decisions than was normal policy. However, the coordination at higher levels drew many complaints. Several are listed below:

1. District 10 had asked the Bureau of Tests to convert specifications originally. The Bureau of Tests in turn requested that District 10 do the revisions and send them in for review. Only after a meeting was called by the Metric Research Project Coordinator to set a time schedule for design of the project was the coordinated effort on specifications accomplished.

2. The foundation report for the bridge was prepared using kg/cm^2. At that time no one had informed the foundation engineer what units to use.

3. The Estimating Section received the supplement to the specifications after they had completed their work.

4. The Bridge Bureau's preliminary design engineer indicated that the project had been chosen before they had an opportunity to see what type of structure was required. He indicated that the site was more complex than what is normally chosen to "try something new on".

5. There were discrepancies between roadway and bridge plans with regard to callout for standard American sizes and degree of rounding used.

6. For the bridge design existing elevations given were to the centimetre while proposed elevations were given to the millimetre.

The District Design Engineer had initially asked that a steering committee be organized at the central office level, but this proposal was rejected. When asked, almost everyone interviewed agreed that a steering committee or metric manager would have been helpful.

2.3.4 Metrication of Right of Way Design and Acquisition

Right-of-way design in all metric units proved to be very simple. Converting original property lines given on recorded deeds from original units to metric units posed no problem, as many old deeds "have to be converted from rods, chains, etc. to feet anyway." All design then was done entirely in metric by the right-of-way designer. The only materials necessary were scales and paper which had already been obtained for the roadway design. As there are no set rules for the exact location of right-of-way lines, other than a reasonable distance outside work limits, the only design aid used is a computer program to calculate areas of take. No revision was necessary, as the input is distances (in ft.) and angles, while output is given in square feet and acres. With distance input in metres the area in square metres can be read in the square foot column and the acre column is ignored. However, it was suggested that the program be revised to give metric output in square metres and hectares if any volume of metric work were to be done. The designer indicated there was no problem working with the horizontal curves in giving offsets for staking.

The plans were prepared showing all metric dimensions on line sheets, metres for distance and hectares for area. Hectares, although not SI recommended, were used because square metres or square kilometres were unsuitable for real estate purposes. However, since the hectare is nearly two and one half times as big as an acre, for smaller areas the number of hectares might have to be carried out to three decimal places. The conversion factors for hectares to acres and metres to feet were given on each plan page, as the appraisers and negotiators would have to do their work in English units to deal with the public. However, no one had any great amount of difficulty in converting the units back to English after a little practice. The summary sheets and the instruments filed with the county auditor were dual dimensioned.

While discussing use of the plans with personnel involved with acquisition, conversation led to what problems they might have in converting to the metric system. Using the market data approach for appraisal (comparison to comparable recorded sales) would be no problem. Instead of using cost per acre it could be simply converted to cost per hectare. However, using the cost (of replacement) approach would be considerably more difficult. This would require the change of several manuals. Here value is determined from various measurements of the property, and all references in the manuals to the customary American system of units would have to be changed to metric.

The summaries of the interviews of those who worked on this project and selected plan sheets may be found in the appendixes of the "Interim Report" which is available from the Federal Highway Administration.

2.4 Metric Project No. 3 (PER-188-03.84)

This project involves 0.685 kilometres of highway relocation and upgrading plus a major culvert. The project is located in Perry County, which is part of ODOT District 5, adjacent to Thornville.

2.4.1 Methods Employed to Obtain Information

Various units within the Ohio Department of Transportation were involved in the design of Metric Project No. 3. These units were:

- Transportation District 5
- Bureau of Roadway Design
- Bureau of Research and Development
- Bureau of Appraisals

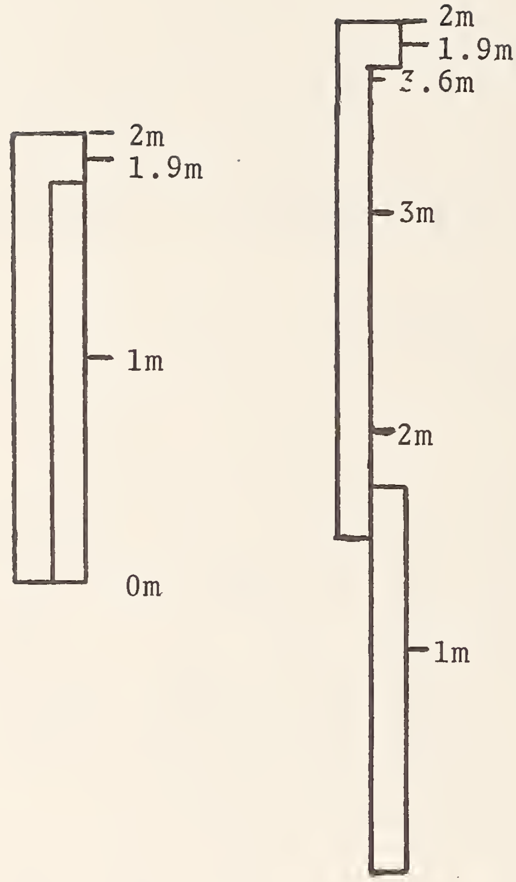
Information was obtained from the individuals involved in the design of this project through one or more of the following methods; written reports, interviews and correspondence. Additionally, the completed plans were reviewed by members of the Metric Research Team and pertinent items noted. Summaries of the interviews are contained in Appendix B-3 and selected plan sheets for this project are contained in Appendix D.

2.4.2 Metrication of Surveying

Original equipment obtained for this project were a 30 metre metallic box tape, a 30 m cloth tape, and a "4 m" level rod. The metallic tape was the only one that could be obtained at the time; and although it was graduated in millimetres, it was flimsy and not suited for highway work. It was later replaced by a drag chain more suited to the purpose; however, this chain was only graduated in decimetres. The basic complaint was the lack of a good quality drag chain suitable for highway work that is graduated to the extent required. There was no complaint with the cloth tape which was used primarily in topo and cross section work. They felt there was a need for an add chain, with the added decimetre marked off to centimetres or millimetres.

The rod obtained for leveling purposes was a standard thirteen (13) foot Philadelphia staff with a metric face, actually being only 3.7 m long. Although they felt that an actual 4 m metric rod should be obtained, they thought the rod was suitable for the job. Their complaint stemmed from the unique construction of the rod (see Figure 6). With the rod collapsed the 2 m mark appears on the overhang of the back section. Extended however, the rod reads up to 3.6 m properly but then jumps again to the overhang where it reads 1.9 and 2. It was noted that this could be a source of error for surveyors used to using a regular 13' Philadelphia rod (assuming 1.9 and 2.0 would be 3.9 and 4) unless caution was exercised. The opinion of the black dots at each dm used to indicate the full metre was not as favorable as that expressed by District Ten personnel. At greater distances these were hard to pick up, and the crew had written the full metre value in red numerals underneath the dots on the face of the rod to make it easier to read. The rods and chains were purchased from a supply company in Columbus, Ohio and were approximately twice the cost of the normal equipment.

Opinions of the actual work were nearly identical to those expressed in District Ten. Although no real training was given, the crew took the equipment, started working with it, and had become accustomed to it in about a week. Each time they were pulled off the job and then came back it took about a half day to get readjusted to using the metric system. The actual time taken to do the work after the adjustment period was about the same as for a project in customary American units, and no more errors were observed.



Collapsed Position

Extended Position

Figure 6. Diagram of 3.7m Leveling Rod

All horizontal measurements were recorded to the nearest millimetre because the first tape available was calibrated to mm. The surveying supervisor, in retrospect, would have preferred to measure to the centimetre because he thinks the mm was too accurate. Current practice is to measure to the nearest 0.01 foot which is equal to approximately 3 mm.

Elevations were recorded to the nearest millimetre for bench marks and to the nearest centimetre for cross sections. Early in the survey, ground elevations were recorded to the decimetre but soon were changed to the nearest cm since it was felt that the dm was not accurate enough. Current practice is to measure ground elevations to the nearest 0.1 foot (approximately 0.3 dm). The problem in this area was that the dm is not accurate enough and the cm is too accurate as compared to 0.1 foot.

Two things that were done by the designer did make the surveyor's job easier on this project. Angles on horizontal curves were left in decimals of degrees on the plan, thus saving the conversion from degree, minute and second to decimals when the crew calculated the curve offsets for centerline layout. Also the customary "plus" was used with 100 m stations and intermediate points at 20 m intervals which made staking out the centerline and control points much easier than it was in District Ten where a new centerline distance designation was tested. The only problem was that the 20 m tape used was not a full station but, rather the length of increments between stations. Thus the crew had to remember what the back "plus" was.

As with Metric Project No. 2, the preliminary design of this project was completed before it was designated as a metric project. The Aerial Engineering Section did not do any of this work in the metric system, since its original work had been completed, excepting to make some metric maps for hydraulic design purposes.

2.4.3 Metrication of Roadway Design

Materials obtained for design work were metric scales, metric rules, metric grid paper and metric size linens. The scales were purchased from a supply company in Columbus, Ohio, from available stock, at approximately the same cost as conventional scales. The quality of these scales were good. The design personnel interviewed indicated that the scales obtained were sufficient for

their work. Folding 2 metre rules were purchased for field check work. Grid paper was purchased from a Cleveland, Ohio distributor at a slightly higher cost than conventional paper. Linens (A1 format) were provided by ODOT Central Office, as they were for Metric Project No. 2. Print paper was cut to A1 size from roll stock. Metric horizontal curve templates were available but at a cost of $150 per set. The District decided that the cost for these templates was prohibitive for only one design job and the designers made do with conventional templates. Points were plotted and a fairly good fit was obtained using the regular ones.

Revision of standard drawings proved no real problem, and it took approximately one week to revise those standards necessary for the project. The basic criterion used to rationalize dimensions of the standards was that the dimension of units formed in the field would be rounded to nominal metric dimensions. The standard drawings were provided to the District by Central Office (C.O.) Design Development on A1 format. District personnel then eradicated all dimensions and replaced them with metric dimensions. None of the standards were redrawn so the revised drawings were not to true scale.

The typical section was the one commonly used for a project of this type with dimensions rounded to nominal metric dimensions (e.g. 3.60 m lane width) with the one exception that pavement and shoulders cross slopes were direct conversions into meters/meter of 3/16" per ft., 1/2" per ft., and 1"/ft. normally used. Side slopes however, remained in the commonly used ratios, 2:1, 4:1, etc. Those working with these could see no advantage in changing this to a percent because a ratio is the same regardless of the unit of measurement. The checker did, however, express the opinion that a separate metric typical section should be developed.

Although no geometric design aids were revised for the project, the designer worked all alignment and profile in metric and had little trouble with it. Standard site distance charts were used with curve lengths converted to customary American units to use them. Vertical curve elevations were given every 5 metres because the designers' opinion was that the nominal 25 feet spacing was too long to begin with and using 10 metres would make it even worse. This opinion was also expressed by the checker and differs from that previously given on the other project. A

definition of curvature based on a 100 metre arc was used for the horizontal curves on this project. No tables were changed but this did not seem to present a problem to the designers; however, no spirals were required in this job. Horizontal curve angles were left in degrees and decimals of a degree and this made the work easier for both the designers and the surveyors. The geometrics review engineer (C.O.) expressed the opinion that the definition for the horizontal curve should have been a 20 metre arc since this would have agreed with the 20 m staking of the project. No-one else shared this opinion.

For stationing, 100 metre increments were used with a "+" to indicate intermediate locations. The designers could see no reason to change from the conventional method to a more confusing way, as was done on Metric Project No. 2. The "+" method saves writing on the plans and makes field staking easier. The geometrics reviewer expressed a fear of the same problem as noted by the surveyors, i.e. having to remember the preceding plus when using a 20 m tape.

For plan preparation, the scales used were:

Plan	= 1:400
Vertical Profile	= 1:100
Horizontal Profile	= 1:400
Cross Sections	= 1:100
Culvert Details	= 1:100

The 1:400 scale for the roadway line sheets made it convenient to fit the 100 metre stations on the A1 format plan and profile sheets. Designers preferred this to the method normally employed since it gave them more room on a sheet.

No particular difficulty was experienced by those drawing up the plans with the exception of the lack of horizontal curve templates. In fact they preferred the somewhat larger scales used for plan and profile sheets and cross-sections. The draftsman indicated that in drawing some details it might take some time to get used to picking the proper metric scale to make the drawing fit. However, he indicated he would rather learn to use the metric scales by trial and error rather than having the aid of a comparison chart to customary American scales as suggested by the bridge detailer on Metric Project Two.

Calculations of estimated plan quantities were easier for all those interviewed, especially earthwork and seeding. Here the use of 20 m as the cross section spacing made calculations of earthwork volumes and seeding areas a simple movement of the decimal point one space to the right on the sum of end areas and lengths respectively. The only negative opinion expressed was from the checker who said it's "too easy". He indicated that most errors were in location of the decimal point because everything was multiplied by ten all the time. With the unfamiliar units this difference of ten times is not that easy to spot. However, most felt that once familiarity with the units is obtained, there should be no problem in spotting an error like this. In general, most of the comments by design personnel in District Five, did parallel those expressed by those in District Ten.

Because of lack of metric design aids and a strict time schedule very little of the drainage design was done in metric. In general, calculations were done in customary American units and the results converted to metric with suggested pipe sizes taken from ASTM and sod and ditch widths rounded to nominal metric. This then took about 25% more time than normally required. The drainage designer indicated that had all the metric design aids been available the work would not have taken any more time or had been any more difficult. The only calculations done entirely metric was the design runoff for the drainage area of the large culvert on the project. Aerial Engineering prepared a metric map for the drainage area and the metric form of the equation used to estimate peak runoff was used. The drainage designer stated that he wished he had done this for all drainage areas on the project.

Estimating for this project was done by the C.O. Estimating Section. The job quantities were converted to customary American units, the total item cost calculated using conventional rates and methods and then the unit metric cost obtained. The basic reason for using this method was that the estimator did not have enough time to do the estimate in metric all the way. The only items that gave the estimator any problems were those quantities where cubic or square metre were used in place of both cubic or square yards or feet. Special items and lump sum items presented a problem too. Cost estimates were made a little higher than normal because of the metric aspects of

the project. This job was only slightly more difficult than normal but the estimator felt that a larger job, where more use would have to be made of the plans (especially mass diagrams for earthwork), would be much harder. He felt also that conversion of earthwork tabulation forms would be difficult, but once forms were converted, along with material cost tabulations, the estimating of a project in metric units would present no problems.

2.4.4 Metrication of Right-of-Way Design and Acquisition.

The design of Right-of-Way plans was the same as that used by District Ten. Original property lines were obtained from deeds by converting the distances in rods, chains and feet directly to metres. This posed no problems for the designer as he generally has to convert many distances in rods and chains to feet anyway. From here all work was done in metric and the plans made only in metric units. Only the summary sheets differed from those used on the other project. Here separate sheets were made, one metric and one customary American. The computer program used to calculate areas did not require revision. With distance input in metres, the area in square metres could be read in the square foot column of the program output and the acreage column ignored. The area in hectares was then given to the thousandths place, since this unit of area is larger than the acre which usually is taken to the hundredths place.

This work proved no more difficult than usual, except the designer indicated that he had trouble obtaining a metric scale. As everyone else stated, metric horizontal curve templates would have been quite useful. With regard to working with the plans neither the appraisers or negotiators expressed any problems.

Unlike in the previous project, HOC-93-00.14, for this particular project appraisals were made in both metric and customary American units and the negotiators did try to discuss the metric system with the property owners.

Because the appraisal was done in both systems the fee charge by the fee appraiser per parcel was increased one third from $300 to $400. Because the market data approach was used he indicated that it would be no trouble to do the appraisal strictly metric and that cost should not vary appreciably. As indicated by District Ten, only in

the cost approach, which is rarely used, would there be any problem in converting to metric.

The negotiators took the plans and appraisals and prepared letters to each property owner with dimensions in dual units and made conversions on the plans to show dual dimensions. They also included with the letters and plans a conversion table. In general the property owners reaction was one of apathy. They did not care to hear about the metric system, and most did not even care about the measurements in particular. They just wanted to know how much. It must be mentioned that most of the property owners were senior citizens and felt they would not be around when the metric system was finally adopted. However, the appraisal reviewer indicated that he thought that appraisals should be done in metric on metric jobs and negotiators should continue the approach used in this project. If nothing else, any exposure of the public to the metric system can't possibly hurt. The negotiators themselves had little trouble working with the plans, just a little more time was involved (because of dual dimensions) in preparing the plans and letters to show property owners.

In general, the only difference expressed concerning Right-of-Way between this project and the HOC-93-0.14 project was the usefulness of appraising and negotiating in metric units.

2.4.5 Comparison of Metric Aspects of Metric Project No. 2 and Metric Project No. 3.

Both projects were quite similar in the methods employed for surveying and design. However, major differences were apparent in the methods of actual plan preparation and dimensioning of standards and typical sections.

Field Surveying for both projects was strictly metric using only metric equipment. All geometric design computations and quantity calculations were done using metric units. Since revision of the specifications was a joint effort of both districts and central office bureaus the metric units used were the same. These are as follows:

Quantity	Unit	Symbol
Length	metre	m
	millimetre	mm
	kilometre	km
	micrometre	μm
Area	square metre	m^2
	square millimetre	mm^2
Volume	cubic metre	m^3
	litre (for liquids)	l
Mass	kilogram	kg
	tonne (1000 kg)	t
Force	newton	N
	kilonewton	kN
	meganewton	MN
Pressure or stress	kilonewton per square metre	kN/m^2
	meganewton per square metre	MN/m^2
Temperature	degree Celsius	C

Both districts approached hydraulic design in the same manner, doing calculations in metric units to the extent possible considering the limitation of having to use design aids still in customary American units. Since only the Hocking-93-0.14 project involved a bridge, no comparison could be made for this area of design.

Major differences in the preparation of plans were as follows:

Typical Section: Although the typical sections used on the two projects were different the methods of treating widths and depths were the same, both districts rounded these dimensions to nominal metric. However, the cross-slopes were treated differently. Pavement and shoulder slopes on the Hocking project were given in percents which were rounded to even numbers, while on the Perry project these were given in metres per metre but left in the exact equivalent to the original inches per foot. The former

is preferred for ease of construction using metric units. Side slopes on the Hocking project were also given in percent, while these were left in the common ratio form on the Perry project. In this case the latter is preferred, as a ratio is the same regardless of units of measurement and most construction personnel are well acquainted with this method of designating side slopes.

Standard Drawings: Although both districts treated redimensioning of units built in field the same, rounding these to nominal metric sizes, the treatment of prefabricated units was somewhat different. While dimensions were slightly rounded on the Hocking project, exact equivalents were used on the Perry project. The latter method was preferred by the majority of people interviewed by the research team. Their basic reason was that as long as the only material available would be customary American sizes these exact sizes should be called for regardless of the units of measurement.

Plan Preparation: An A1 metric format (594mm x 841mm or 23.4" x 33.1" as compared to the current standard size of 22" x 36") was chosen for the sheet sizes for both projects. Scales chosen for the plan and profile sheets were 1:500 (horizontal) for the Hocking Co. project and 1:400 (horizontal) for the Perry Co. project and 1:100 (vertical) for both projects. Scales chosen for cross section views and culvert details were 1:100 (horizontal and vertical) for both projects. Scales used for the bridge plans of the Hocking Co. project were 1:200 for the Site Plan, 1:100 for the General Plan and 1:10, 1:20, 1:40 for detail views and these proved satisfactory. Although the SI recommended series of scales is 1, 2, 5 and 10^x multiples of them, the 1:400 scale with two full stations per sheet (as used) on the Perry project was generally preferred by the C.O. Reviewers (who worked on both plans) because the plans were "much easier to follow" in locating points on the project and there was more room to add topographic details on each sheet. The Hocking project used 2-1/2 stations per sheet. Vertical curve elevations were given at 10 metre intervals on the Hocking plans and at 5 metre intervals on the Perry project. Although in most cases it was believed that 10 metre intervals would suffice, a 5 metre interval might prove useful for sharper curves.

A major difference in the method of designating stationing was employed on the two projects. Stationing for the Hocking project employed a comma in lieu of the "+" commonly used and large and small numbers (e.g. Sta. $5,4_{32.10}$), while the Perry project was the same as normally used with the exception that stations were 100 metres instead of 100 feet (e.g. 54+32.10). The latter method was preferred because the former was difficult if not impossible to type properly and required more numbers to be written on plan sheets and survey layout stakes. Furthermore, the Hocking method was confusing to most people who used the plans other than the ones actually involved in the plan preparation stage.

The method of measuring horizontal angles was different on the two projects. The Hocking County project used the conventional method of degrees (360° circle), minutes and seconds while the Perry County project used degrees and decimals of a degree. While the SI recommends the radian as the unit for plane angle it does permit the use of the arc degree and its decimal submultiples when the radian is not a convenient unit. The use of the decimal degree on the Perry County project proved very satisfactory and is favored over the customary method.

Education: District 10 personnel were given some training in the metric system before preparation of the Hocking roadway plans. Bridge Bureau personnel who prepared the bridge plans for the Hocking project and District 5 personnel who prepared the Perry plans were responsible for educating themselves. There seemed to be little difference in the speed of adaptation to work in the metric system between the two cases.

Chapter 3 -- Phase 2. Construction of Metric Projects

3.1 Introduction

This chapter will report on the progress made toward the construction of the two metric projects designed under phase 1 and will repeat the Interim Report discussion of the construction of Metric Project No. 1.

3.2 Metric Project No. 1

As mentioned in the previous Chapter, the design and construction of this project is not specifically included in this research project but will be discussed briefly to provide general information.

Prior to the letting of the contract a meeting was held between representatives of ODOT and 5 contractors who had expressed interest in the contract. At this meeting the contractors were informed relative to requirements for the metric project. Specifically, they were advised that: (a) All measurements will be in metric units (b) All materials arriving at the job site will be listed in metric units (c) Bituminous material will be applied using metric rates of application (d) Truck scales at the bituminous plant and batching scales will not be converted due to time and cost involved. (e) In lieu of this, the contractor will furnish a conversion chart for plant inspectors and ticket writers.

Three bids were received on the project and did not indicate any increase in bids due to use of metric units. A detailed pre-construction conference was held with the successful bidder to again outline the requirements of the job. The District 5 Testing Engineer held brief training sessions (1 hour) to acquaint ODOT personnel with the conversion charts and record keeping in metric units.

Project personnel were contacted again as the project neared completion and all indications were that there had been no problems. A check of the project records indicated

no significant increase in errors due to use of metric units. All indications are that approximately one day was required to acquaint oneself with the unfamiliar system and after that all proceeded smoothly.

In summary, work on the project went well despite the use of the unfamiliar metric system and it was apparent that both the State and Contractor's men learned the system very quickly.

3.3 Metric Project No. 2 (HOC-93-00.14)

This section describes the activities on this project after completion of the design phase and acquisition of the right-of-way. It discusses the pre-contract award stage, the bidding stage, the pre-construction stage and the construction stage.

3.3.1 Pre-Contract Award Stage

This project was first advertised on August 26, 1974. The advertising notice announced that bidding proposals for this project were being solicited with the bids to be opened on September 10, 1974. Approximately one week prior to the first advertisement, a bidding pamphlet was sent to all addressees on the Department's normal mailing list of prospective bidders. This pamphlet contained a brief description of the project, a listing of approximate unit quantities and an announcement of a pre-bid conference.

a. Project Description

Project No. 428

HOCKING COUNTY

State Route 93-Section 0.14(0,2oo)

METRIC PROJECT

Date Set for Completion: October 31, 1975

Type: 404 on 301 & Structure

For improving Section HOC-93-0.14(0,2oo), State Route No. 93 in Washington Township, Hocking County, Ohio, in accordance with the plans and specifications by grading, draining and paving with asphalt concrete (404) on a bituminous aggregate base (301) and by constructing: Bridge No. HOC-93-0,984, a prestressed non-composite box beam superstructure with concrete substructure (spans 10.325 m - 10.650 m - 10.325 m, roadway 13.41 ± m between guardrails), over West Branch Raccoon Creek.

Pavement width 7.20 m. Project length 1,340.00 m or 1.340 km. Work length 1,698.40 m or 1.698 km.

b. <u>List of Approximate Unit Quantities</u>

This list contained all bid items with the estimated quantities for each. All quantities were shown in metric units. The purpose of this listing is to assist the bidder in the preparation of his tender. A complete listing of these approximate quantities is reproduced at the end of this chapter.

c. <u>Pre-Bid Conference</u>

The following announcement of this meeting was included in the bidding pamphlet:

A Pre-Bid Conference will be held in the District Deputy Director's Office, Muskingum Drive, Marietta, Ohio 45750 on September 4, 1974 at 10:30 A.M. The purpose of this conference is to provide guidance and assistance in interpretation of plans to prospective bidders on this metric project. Attendees are urged to review the plans in detail in advance in order to assure that any questions they may have regarding the plans or preparation of estimates may be discussed at the conference.

Those individuals desiring to attend this conference are requested to notify Mr. Max R. Farley, District Deputy

Director at the above address preferably before August 30, 1974, Telephone (614) 373-0212.

The pre-bid conference was held on September 4, 1974 as announced. In attendance were:

- 6 Representatives from ODOT Central Office Bureaus
- 10 Representatives from ODOT District 10
- 5 Representatives of Contractors
- 4 Representatives of material suppliers

The meeting was opened with a description of the metric research project and a statement that the reasons for the pre-bid conference were to explain the metric aspects of the project to prospective bidders, to state what was required of the contractor and to answer questions. Next, two plan notes which dealt particularly with metric requirements were read and explained.

The first note to be read is as follows:
UNITS OF MEASUREMENT: --

"This project was designed and shall be constructed using the "Metric S.I." system as the unit of measurement which was adopted per international Standards Organization agreements. The Manual E 380-72 issued by the "AMERICAN SOCIETY OF TESTING AND MATERIALS" was used as a basis throughout the project. Elevations are given in metres, distances in metres and millimetres. The method of stationing used identifies the number of metres which is directly before the decimal point, with the kilometres separated by a comma, i.e., Station 1, 230.40 is 1230.40 m from point of origin or point 0,000. The project is staked at 20 metre intervals. The Dcm is the degree of curvature metric. 1° Dcm is a curve with an arc length of 100 m at 1° central angle. Deflection angles used to stake out the project were computed by the District 10 office. The tables are on file in the office of Contract Sales of The Ohio Department of Transportation, Columbus, Ohio and the District 10 office and are available to the contractor upon his request. The "1973 State of Ohio Department of Transportation Construction and Material Specification" for this project

is ammended with the State of Ohio Supplemental Specification No. 1026. All Elevations are based on U.S.G.S. Datum" (sic).

It was then pointed out that the note meant exactly what it said "the project shall be constructed in the metric system". Materials are expected to be delivered to the project in metric units and all documentation of these materials will be in the metric system. The contractor is not to "do everything in the English system and just convert it to metric. We will do things in the metric - supposedly operate 100% within the metric system on the project. We don't need any English measuring tools or any English weights or anything. We'll do everything in the metric system" (George D. Dougan, Dist. 10 Engineer of Tests). It was further explained that the District hoped the contractor would get his suppliers to invoice him in metric terms. If this proved to be impossible, then the contractor would be expected to convert the suppliers' invoices to metric terms and submit his invoice to ODOT in the metric system.

District representatives explained that they expect the operation of the ready mixed concrete plant and the blacktop plant (material suppliers) to be converted to the metric system. The output from these plants would be produced in the metric system. Their scales and dispensing equipment were to be metricated to the point where they would actually produce ready mixed concrete and blacktop in metric quantities. The data sheets for the blacktop and the design for the concrete will be submitted to the production plant in the metric system.

The contractors were told that they were required to use metric measuring equipment (such as scales, tapes, chains and leveling rods) on the project. They were advised to order this equipment early to assure obtaining it on time. Also, they were alerted to the possibility that the measuring equipment would probably be more expensive than that they now use. The Surveying Supervisor for the District offered to assist the contractor's crews if they encountered any problems due to the metric aspects of the project.

The second note read is as follows:

SPECIAL PROJECT DOCUMENTATION:-

By virtue of the unique nature of this project, the contractor shall report to the Director through documentation his experiences in executing the contract with regards to the Metric S.I. units of measurement.

Points to be documented are:

(1) Procurement of construction materials in agreement with the plans and the specifications.
(2) Performance of the Item 623 "Construction Layout Stakes" in the Metric S.I.
(3) Additional education of all personnel under the contractor's responsibility.
(4) Problems encountered establishing unit prices for bidding purposes.
(5) Other pertinent information which the contractor feels that can be of benefit to be incorporated in the final summary report which will be prepared by the Ohio Department of Transportation.

The above documentation shall be submitted to the Ohio Department of Transportation at a final conference not later than three (3) months after acceptance of the project.

In addition to the requirements as set forth above the following will be required:

1. An interview with the Contractor and his estimator within two weeks after contract is awarded. This is necessary for inclusion in the metric research study's final report.
2. Interviews with the Contractor and his key personnel during construction of the project.
3. Interviews with the Contractor and his key personnel within 3 months after completion of the work.

Payment for all of the above will be included in ITEM SPECIAL Project Documentation (sic).

After the note was read, the attendees were told that the purpose of the note (and accompanying pay item) was to reimburse the contractor for the time and expenses necessary to keep complete and accurate documentation of this project; to prepare and submit the documentation to ODOT within three months after the project's acceptance; and to attend the required interviews by the Metric Research Project Team. It was explained that the documentation was necessary to record any problems the contractor might experience in the construction of the project; including (but not limited to) procurement of materials and supplies, education of employees, understanding of the metric aspects of the project, surveying and costs.

Questions were asked by a ready mixed concrete supplier concerning what to do if the necessary equipment to convert a plant could not be procured. He was told if he could show that an "all out" attempt to obtain the necessary equipment had been made but that it was unavailable, then he could produce his products in customary units and convert his invoices to metric units for delivery to the project site. The supplier said he had investigated purchasing check weights in kilograms and was told they were available. However, his past experience has been that sometimes you order "available" items and get them six months later. He also said he was willing to convert his scales if dial facings (in metric units) were available.

The District Construction Engineer reminded the contractors that there is a temporary bridge on the project. By ODOT regulations the plans for this bridge are to be prepared by a registered engineer employed by the contractor. The plans for the temporary bridge and temporary runaround are to be prepared in metric units and submitted to the Department for approval.

The meeting was closed with a brief discussion concerning education. Mr. Dougan offered to assist any contractor who wished to hold educational sessions for his employees. He explained the extent of his assistance would be to sit in on the meetings, not to conduct them, and to

explain the plans and anything concerning the metric system that they might have questions about.

3.3.2 Bidding Stage

a. Summary and Analysis of Bids Received

Four bids were received for the construction of this project. The summary of these bids is listed below:

Bidder	Total Bid
1. Engle Construction Company McArthur, Ohio	$686,047.38
2. Danis Industries Corporation Dayton, Ohio	879,564.87
3. J.J. Blazer Construction Co., Inc. Wheelersburg, Ohio	1,036,664.32
4. L.R. Skelton and Company Columbus, Ohio	1,072,353.26

The ODOT estimate was $860,000.00. The range in the total bid amounts is not unusual on projects of this size, and the total amounts do not appear to be affected substantially by the fact that this is a metric project. Bidders 1, 3 and 4 were represented at the pre-bid conference.

To determine if the bid prices of any particular items were substantially affected by the metric nature of the project, all unit bid prices were converted to customary American units and compared to unit bid prices submitted by the four contractors for prior bids in 1974 on other projects. In general, converted unit prices all fell within the range encompassed by previous unit prices with but two exceptions.

It was noted that the low bidder's converted unit prices for cubic yard quantities were lower than normal. At first it was thought this could have been caused by applying cubic yard prices to cubic metre quantities, when in fact the cubic yard is only about three fourths of a cubic metre. However, during the post-bid interview (see below) with this contractor it was ascertained that the

unit price had been calculated correctly and that factors not involved with metrication had caused the lower unit price.

The other exception was a definite error. The high bidder's unit prices for litres of tack coat and litres of seal coat were about 15 times that which would normally be expected. This was almost assuredly due to a conversion error in the relationship of litres to gallons. One gallon is equal to approximately 3.79 litres. If this was reversed (i.e. 3.79 gallons equals 1 litre), it would cause an error of the magnitude observed. Correction of this error would have made him the normal three bidder.

b. Post-Bid Conference

The contract was awarded to the low bidder, Engle Construction Company of McArthur, Ohio, on September 10, 1974. A post-bid conference was held on October 17, 1974 to discuss the bidding aspects of the contract and any progress to date. In attendance were representatives of the Contractor, the District 10 construction office and the metric research team. Mr. Ronald Sharrett, the Contractor's chief engineer, was asked if there was anything in the metric plans that affected his bid, other than the special documentation item. He replied that "he had discussed this with other members of the company to some length trying to see if there was any particular problem. As near as we can tell we really can't determine any problem that really arose in preparing the bid. It was just a matter of conversion."

He further indicated that the only feasible way they could prepare the bid was to convert all quantities back to customary American units, since "all previous cost records are naturally in the English system." From the total cost of each bid item metric unit prices were then calculated. The only calculations done in metric units by the contractor during preparation of the bid were plan quantity checks on a few of the more important bid items.

In other statements, the Contractor's representatives said that they had no real problems in understanding the relationship between metric units and customary American units. Of necessity they sat down and discussed the change to metric and how to prepare to do it. They used a table for conversion of units from one system to another. They had some conceptual problems in perceiving how much a metre is or 100 m vs 100 ft. or a cubic metre vs. a cubic yard and continued to backcheck themselves to avoid errors. These conceptual problems and backchecking to avoid errors are the main reasons the estimating procedure took longer than normal. They intend to use their regular equipment for excavation work, if at all possible. Their bid did not take into account any possibility of modifying their equipment to obtain exact metric trench widths for items such as drainage pipes or for the possibility of needing extra backfilling (at relatively high cost) to refill over (that actually required) excavated trenches.

Mr. Sharrett was asked if he had re-examined his bid in the light that he was 20.2% under the State estimate and 22% under the next lowest bidder. His answer was that he had re-examined the bid twice since, naturally, they felt that they may have done something wrong. However, after re-examination they are happy with the bid and could find no errors. One reason for the relatively low bid is that their company's headquarters are located only about 12 miles from the job site.

Next, the Contractor was asked if there was any item where he foresaw some construction problems because the item was in metric and, therefore, increased the bid price to compensate. His reply was that there were none. He added that the only forseeable problem was getting foremen indoctrinated to working in the metric system, which would be a considerable change from the way they are accustomed to doing their work.

Asked if there was anything else on the plans or in the way the plans were prepared that he anticipated may cause troubles, Mr. Sharrett replied that the only thing was the way slopes were indicated in percentages instead of the usual ratios (2:1, 4:1, 8:1, etc.). He thinks this may cause some problems in layout.

In preparing his bid, all material suppliers, except the aggregate supplier, had quoted in metric units and would invoice in metric. The Contractor will have to convert the aggregate invoices himself. The ready mixed concrete supplier said he would convert his plant to produce metric quantities and would supply his product to the job in actual metric units. There were some increases in the unit price quotes received by the Contractor. An appreciable increase was noted in the price of ring necks for catch basins and for the ready mixed concrete. Apparently, in the case of the ready mixed concrete, this increase was to compensate the supplier for converting his plant to metric. Mr. Sharrett did not know the percentage increase but estimated the total to be about $1800. The Contractor said he was not concerned about the aggregate supplier furnishing him with non-metric aggregates. He said he felt that there really was no change as far as sieve sizes or gradation but if the provided aggregates did not pass the State's inspection then it would be the aggregate supplier's responsibility to comply. Blacktop will be supplied in metric units, but a firm price has not yet been negotiated and how much more (than customary) the metric material will cost is not known. However, the blacktop supplier does intend to convert his plant but the added cost per unit of material should be slight since there is considerably more asphalt concrete on the project than portland cement concrete.

Asked if there was anything else he wanted to add, Mr. Sharrett said he had not grasped the full impact on how to bid the special documentation item and, as his bid reflected, he was the lowest bidder on that item. He repeated that he could foresee problems in layout of the project with the percentage slopes and the different method of designating stationing. However, they do have an

excellent party chief and felt, with the close proximity of their company offices, supervisory personnel could be on hand to help general foremen and the bridge foreman to stay in the right direction. That is the reason they didn't apply anything really appreciably extra to the cost for it being a metric job. The bridge foreman has been selected and, even though he is an older man, seems quite interested in the project. Additionally, two younger field men have approached him asking to work on the project. From these reactions, the Contractor expects no personnel problems in the work on this project.

The problem of obtaining the necessary metric equipment was discussed next. Mr. Sharrett said he is having some problems in obtaining surveying equipment. Literature from supply houses indicated the equipment was available but when ordered he was informed that it would have to be back-ordered. He anticipates no problems with his heavy construction equipment and feels it can be adjusted to metric sizes when necessary.

In closing, the Contractor said he had no particular plans for educating his personnel, except for calling the key people in for a meeting and going over the plans sheet by sheet. Mr. Sharrett prepared the plans for the temporary bridge himself. The main problem in this endeavor was in how to "call out" component sizes. That, and the fact that it took him quite a bit longer than the design of a conventional bridge. For the preparation of the total bid, he estimates it took him about 25% longer than normal. He anticipates the project will be completed on time (October 31, 1975) and foresees no problems.

c. Interview with Ready Mixed Concrete Supplier

The supplier of the ready mixed concrete for this project will be the Hocking Valley Concrete Company. This company was represented at the pre-bid conference. The company has located metric facings for its dial scales but is having difficulty in calibrating beam scales. Apparently, the linkage has to be changed. Attempts were made to obtain

metric check weights but none could be delivered in time. Therefore, the company took some standard pound weights to a local machine shop and had them modified to metric weights. This was a very satisfactory method and the resulting weights met requirements. Water measuring devices will be converted with scale overlays. The total cost of the plant conversion is estimated to be about $3500 versus an original estimate of $2000.

3.3.3 Pre-Construction Stage

A pre-construction conference, attended by representatives of the Contractor, ODOT Central Office Testing Laboratory and District 10, was held on October 2, 1974. Most subjects discussed were about non-metric concerns of the project. The contractor was informed that all suppliers would be expected to furnish all paper work in metric units. The contractor shall assume this task for any suppliers unable to do so. Portland cement concrete ready mix and asphalt concrete shall be produced utilizing metric design and measurement. The District 10 Testing Engineer volunteered his assistance in any metric schools that the contractor will hold for his employees. The "Special Project Documentation" notes were discussed in depth in order that there was full understanding concerning these unique requirements.

3.3.4 Construction Stage

a. First Monthly Progress Report

The first monthly progress meeting to discuss the progress on this project was held in the District offices on November 29, 1974. The meeting was attended by three District 10 representatives and four representatives of the contractor.

Two engineers from the District had visited the Hocking Valley Concrete plant at Logan. The concrete company indicated they should be able to convert their aggregate and cement scales in the next two or three weeks. Their water

meter has already been changed to measure water in litres, and they had some 20 kg test weights made. Also, Hocking Valley Concrete agreed to document the costs and problems they had in procuring the components necessary to convert their plant to the metric system, and would provide the State with a copy. Mr. Ron Sharrett, Chief Engineer of the Engle Construction Company, said that Brewer & Brewer of Chillicothe, the asphalt subcontractor, had indicated that there would be no trouble in converting their plant to the metric system.

The problem with giving pipe sizes to the nearest centimetre was discussed. Charles Mansfield, Project Engineer, pointed out that the supplier sends the pipe with the closest English measurement. As an example, where the plans call for a 310 mm pipe, the supplier actually sends a 12" which is a 305 mm pipe. For pipes covered under Sections 706.02 or 706.03 of the Construction and Material Specifications, the tolerance is ± 5 mm, and therefore half of the pipes sent for this size could be out of tolerance.

Mass/metre conversion table in supplemental specification for No. 9 reinforcing steel is most likely in error. This is to be checked by the Department. Contractor was told plan weight was most likely right.

Project check sections have been taken and plotted, and the only area in question is at Station 1,3oo. Additional checks are to be taken in this area before any work is performed. Contractor was asked if he expected any problems with odd slopes, 37.4% and 46.1%, in transition area. They stated they expected none.

Ron Sharrett stated he was unable to get the needed measuring devices for this project. The District-Design Engineer stated he would try to help in this. The Project Engineer advised everyone that in driving piling for temporary bridge, bedrock seems to be higher than plan. If this is true for the new bridge, it is noted that the footer can be raised only 1 metre by the Highway Director.

Mr. McCloskey, the District Construction Engineer, advised that he is having signs made and erected on each end of the project stating it is a metric project, the first in the U.S.

b. Second Monthly Progress Report

The second monthly progress meeting has not been held as of the date (December 31, 1974) of this report. The Contractor reports that the project is 15.7% completed, vs. 19% projected. Two large drainage pipes have been installed. The temporary runaround bridge has been completed and fill is going in for the temporary runaround road. Weather permitting, the temporary road will be paved next week, traffic detour onto the runaround, and construction on the bridge started. All materials to date have been invoiced in metrics. Two shipping lists were sent for reinforcing bars, one in customary units and one in metric units. Surveying measuring equipment was difficult to obtain and they had to settle for less equipment than they wanted. Wind up steel tapes came with metric units on one edge and customary units on the other edge. The customary units were painted out to prevent the workers using them as a "crutch". So far no carpenter's folding rules are available and steel tapes will probably have to be used; an inconvenience. Prices for the measuring equipment has been only slightly higher than normal. The on-job workers have had no problems understanding the metric aspects of the plans and the project layout has gone "maybe even better" than normal layout work. The ready mixed concrete supplier has completed the conversion of his plant and will be supplying "metric concrete" for headwalls next week.

3.4 Metric Project No. 3 (PER-188-03.84)

This project has not progressed as far as Project No. 2 due to a six week later start. The pre-contract award stage and the bidding stage are all that can be discussed in depth.

3.4.1 Pre-Contract Award Stage

This project was first advertised on October 2, 1974. The advertising notice announced that bids would be opened on October 22, 1974 for this project. At about the same date, a bidding pamphlet, containing a brief description of the project, a listing of approximate unit quantities and an announcement of a pre-bid conference, was mailed to all normal recipients.

a. Project Description

Project No. 494

PERRY COUNTY

State Route 188-Section 3.84(6.18Km)

(METRIC RESEARCH PROJECT NO. 3)

Date Set for Completion: September 30, 1975
Type: 404 on 301

For improving Section PER-188-3.84(6.18Km) State Route No. 188 in the Village of Thornville, Thorn Township, Perry County, Ohio, in accordance with plans and specifications by grading, draining and paving with asphalt concrete on a bituminous aggregate base.

Pavement width 7.2 Meters. Project length 590 m or 0.590 Km. Work length 685 m or 0.685 Km.

b. List of Approximate Unit Quantities

This list contained all bid items with the estimated quantites for each. All quantities were shown in metric units. The purpose of this listing is to assist the bidder in the preparation of tender. A complete listing of these approximate quantities is reproduced at the end of this chapter.

c. Pre-Bid Conference

The following announcement of this meeting was included in the bidding pamphlet:

A Pre-Bid Conference will be held in the District Deputy Director's Office, 1200 West Church Street, Newark, Ohio 43055 on October 16, 1974 at 10:30 A.M. The purpose of this conference is to provide guidance and assistance in interpretation of plans to prospective bidders on this metric project. Attendees are urged to review the plans in detail in advance in order to assure that any questions they may have regarding the plans or preparation of estimates may be discussed at the conference.

Those individuals desiring to attend this conference are requested to notify Mr. Stephen F. Petty, District Deputy Director at the above address preferably before October 11, 1974, Telephone (614) 344-1116.

The pre-bid conference was held on October 16, 1974 as scheduled. In attendance were:

- 5 Representatives from ODOT Central Office Bureaus
- 5 Representatives from ODOT District 5
- 1 Contractor representative
- 2 Representatives of a material supplier

As can be seen from the above list, the turnout of contractors and suppliers was not nearly as good as for Metric Project No. 2.

This meeting followed the same pattern as that for the HOC-93-0,14 project. The two special notes "Units of Measure" and "Item Special-Project Documentation" were read and discussed. The only difference in the notes being that the method of stationing is the same as normally used except with 100 metre stations instead of 100 feet stations. Primary questions concerned what was required by the special documentation, and this was explained, and what was required for material invoicing. Considerable discussion ensued on

the subject of material invoicing, but it was resolved in the following instructions. The contractor and suppliers were told that all materials must be delivered to the site in metric units. If the supplier did not convert his plant to metric operation then either the contractor or the supplier must convert his delivery tickets to metric. The same thing applies to hardware items such as drainage pipes and guardrail. The attendees were advised to order any required metric measuring equipment as soon as possible. No other pertinent subjects were discussed.

3.4.2 Bidding Stage

a. Summary and Analysis of Bids Received

Three bids were received for the construction of this project. The summary of these bids is listed below:

Bidder	Total Bid
1. Dodge-Irelan, Inc. Dublin, Ohio	281,866.36
2. Shelly and Sands, Inc. Zanesville, Ohio	323,407.94
3. Maiden and Jenkins Constr. Co. Nelsonville, Ohio	415,036.69

The ODOT estimate was $315,000.00. As with the HOC-93-0.14 project, the range of bid amounts is not unusual nor do they appear to have been greatly increased due to the metric nature of the project. The highest bidder attended this pre-bid conference, but neither of the other two bidders attended this conference or the pre-bid conference for HOC-93-0.14.

The same procedure used on Metric Project No. 2 was applied to this project to determine any irregularities in unit bid prices. No unit prices for this project appeared abnormal. However, the low bidder's price for the special documentation item was extremely low, only $100.00. It was observed that the low bidder had submitted only one prior bid on other ODOT projects during 1974. All other

bidders on this project and the HOC-93-0.14 project have regularly submitted bids on highway projects.

b. Post-Bid Conference

The contract was awarded to Dodge-Irelan, Inc. of Dublin, Ohio, on October 25, 1974. A post-bid conference was held with Bill Ruxton, Chief Estimator and project supervisor for Dodge-Irelan, on December 20, 1974. The only other attendees were three members of the Metric Research Study Team.

Mr. Ruxton said it was not difficult for him to prepare the bid, even though he had not worked in metric units before and his only exposure to the metric system was in school. He had no working knowledge of the metric system, just an awareness. He used a handbook to make conversions and no particular item gave him trouble. He went through the entire proposal and converted all bid items to customary units, then figured the total price for each item using current prices and divided the total by the metric quantity to obtain the metric unit price. He back-checked his work several times and found one mistake in conversion. However, this was such a "screwy number" that he spotted it easily during his backchecking. He said that the only problem he had in the conversion process was whether a number was "1 over x or x over 1".

The only item with a price increase, because of the metric aspect, was that of construction layout. He figured metrics would not make any difference in the price of the rest of the items. The difference for the construction layout increase was $300 of a total of $5,200. This was figured for the engineer who will have to do the actual surveying, and this will be subcontracted to a surveying company.

The contractor has not tried to obtain any metric equipment to work with. As stated above, the surveying will be done by another firm and that firm has worked on a metric job before and has all the necessary equipment.

Once he accepted the fact that the plans were in metric units, Mr. Ruxton had no problem following them and had no suggestions for changes in the way they were prepared. He thought the plans had been presented fairly and the bidders were able to prepare a fair bid.

None of Dodge-Irelan's personnel have had previous experience in working in the metric system. Additionally, they all know this is a metric project and have voiced no concern. No training program is planned but supervisors will be there to help if on-the-job workers have problems. Mr. Ruxton discussed the metric aspects of the job with the head of his company. Both agreed that at their ages (45 to 55 years old) it is pretty tough to convert their thinking to the metric system. They feel they are going to be working only another 15-20 years. For younger men its going to be a bit easier because "they'll be working with it the rest of their lives."

The bituminous supplier for this project attended the pre-bid conference and supplied the bituminous material for Metric Project No. 1. The supplier said he could see no problems and, actually, his bid was less than bids received from other suppliers. All drainage pipes will be purchased through a Columbus supply house and will be invoiced in metric units. This supplier foresees no particular problems in the metric units and, in fact, have worked with metric units previously.

Mr. Ruxton was asked why a representative of his company did not attend the pre-bid conference. He replied that they were aware the conference was going to be held but did not attend because all their key personnel were tied up that day on other matters. However, they had wanted to attend the meeting. Subsequent to the meeting, Mr. Ruxton called the District 5 Construction Engineer and obtained a brief summary of what was discussed. He said he questioned the Construction Engineer concerning metric dimensions from suppliers, in particular drainage pipe items, and was told that the pipes would not have to be

exact metric size pipes but could be converted to the metric equivalent of the customary size.

Questioned on his low bid ($100) for the special documentation item, Mr. Ruxton said he had been aware of the presence of this bid item in the plans and the proposal but did not give it any special thought. He added that the fact that this was a metric job did not influence the company's decision to tender a bid. The length, location and quantities fit the type of job they could do and so they bid on it.

Asked if he had anything further to add, Mr. Ruxton wanted to know what would prevent a contractor from building the entire job in customary units if he wanted to do so. He was told he would have to build in metric units and would be so instructed at the pre-construction conference. Also, that the project engineer would be checking on the progress during construction and would control this feature (It must be noted that this subject was discussed at the pre-bid conference and the plan note controlling this feature read and discussed. As mentioned earlier, no representative of Dodge-Irelan, Inc. attended the pre-bid conference).

3.4.3 Construction Stage

Work will not start on this project until April 1, 1975 because the road can not be closed to traffic until that date; and the contractor does not want to work while maintaining two way traffic prior to that date. Because of the late start, the District does not plan to have the pre-construction meeting until late Winter. Since there has been no activity in the Construction stage, there is nothing to report at this time concerning actual construction of the project.

3.5 Future Work

The two metric projects, HOC-93-0.14 and PER-188-03.84, will be completed under the ODOT contracts. During construction of these projects, district construction personnel and the contractors' personnel will be interviewed to ascertain the progress toward completion of the project; and to determine problems, solutions of these problems, opinions and recommendations, all as relate to the metric aspects of the projects. Within three months after the acceptance of each project by the State, each contractor will be interviewed and will submit documentation concerning his experiences in education of employees, surveying, material and equipment procurement, actual costs versus unit prices bid, and other areas.

The Ohio Department of Transportation will publish a final report covering the completion of phase 2 (construction) of its five phase metric work program. This report will be available to interested parties upon receipt of a written request for a copy.

APPROXIMATE UNIT QUANTITIES
HOC-93-0.14

ROADWAY

Quantity	Unit and Description
lump	clearing and grubbing.
26	m pipe removed, 380mm and under.
lump	structure removed.
72,292	cu.m excavation not including embankment construction, as per plan.
93,946	cu.m embankment, as per plan.
11,926	sq.m subgrade compaction
788	cu.m traffic compacted surface, Type A or B.
526	cu.m traffic compacted surface, Type C.
26	each centerline reference monuments.
826.2	m guard rail, Type 5.
12	each anchor assembly.
4	each bridge terminal assembly, Type B.
lump	temporary roads
31	tonne calcium chloride.
130	cu.m water.

Total Roadway.

EROSION CONTROL

11,178	sq.m temporary seeding and mulching.
10	cu.m water.
315	m temporary slope drains.
94	cu.m temporary benches, dikes, dams and sediment basins.
14,000	sq.m mowing.
309	m asphalt paved gutter, Type 2.
52	sq.m riprap, using 150mm reinforced concrete slab.
133	cu.m rock channel protection, Type A.
259	cu.m rock channel protection, Type B.
744	cu.m dumped rock fill, Type B.
64	m paved gutter, Standard Type 4.
28.71	tonne agricultural liming.
45,285	sq.m seeding and mulching.
2,795	sq.m repair seeding and mulching.

EROSION CONTROL (cont.)

Quantity	Unit and Description
10,604	sq.m seeding and mulching, as per plan.
8.61	tonne commercial fertilizer (12-12-12).
15.32	sq.m sodding

Total Erosion Control.

DRAINAGE

15.0	m 150mm conduit, Type F.
25.0	m 200mm conduit, Type C.
42.0	m 310mm conduit, Type D.
28.2	m conduit, Type A: 530mm 706.08 or 706.02 epoxy coated, as per plan; or 610mm 707.05 asbestos bonded, 942.
44.4	m conduit, Type A: 610mm 706.02 Class IV; or 690 mm 707.05 Type C.
79.3	m 1070mm conduit, Type A, 707.07 Type C.
62.2	m conduit, Type A: 1830mm 706.02 Class V epoxy coated, as per plan; or 2440mm 707.07 (2.8mm) asbestos bonded, 942.
9.4	cu. m concrete masonry.
2	each Standard No. 2-2-B catch basin.
1	each Standard No. 5 catch basin, modified as per plan.
1	each Standard No. 4 catch basin, modified as per plan.
300	m 150mm deep pipe underdrains.
3	m aggregate drains for springs, as per plan.
60	m 150mm unclassified pipe underdrains 707.01 Type III or 707.12, as per plan.

Total Drainage.

PAVEMENT

1,867	cu.m bituminous aggregate base: 702.01 (85-100 or AC-20); or 702.09, RT-11 or RT-12.
218	cu.m aggregate base.
366	cu.m asphalt concrete (70-85 or AC-20).
6	cu.m asphalt concrete (driveways) (70-85 or AC-20).

PAVEMENT (cont.)

Quantity	Unit and Description
289	cu.m asphalt concrete (70-85 or AC-20).
773	liter tack coat: 702.04, SS-1, SS-1H, MS-2 or RS-1; or 702.02, RC-70 or RC-250.
6.5	tonne cover aggregate.
4,280	liter seal coat bituminous materials: 702.09, RT-9 or RT-10; 702.02, MC-800 or MC-3000; 702.04, RS-1, RS-2 or CRS-2; or 702.03, CBAE 800.
22	cu.m seal coat cover aggregate, No. 8.
204	sq.m reinforced concrete approach slab (T= 400mm).
11	cu.m stabilized crushed aggregate.

Total Pavement.

BUILDING REMOVAL

lump	Parcel No. 5-AWD, removal of one frame shed.
lump	Parcel No. 6, removal of two hog houses.
lump	Parcel No. 8-WD, removal of one frame barn, and one silo base.

Total Building Removal.

STRUCTURE OVER 6 METER SPAN

Bridge No. HOC-93-0,984

lump	structure removed.
lump	temporary bridge.
lump	cofferdams, cribs and sheeting.
209	cu.m unclassified excavation including rock.
lump	test pile.
83	m steel piles, HP12x53.
13,411	kg reinforcing steel.
7	cu.m Class "C" concrete, superstructure (pier joints).
86	cu.m Class "C" concrete, abutments.
58	cu.m Class "C" concrete, pier caps and columns.
17	cu.m Class "C" concrete, pier footings.
450	sq.m Type "B" waterproofing, modified.

STRUCTURE OVER 6 METER SPAN

Bridge No. HOC-93-0,984 (cont.)

Quantity	Unit and Description
33	each prestressed concrete bridge members.
10	sq.m 25mm thick elastomeric bearing pads.
32	sq.m 25mm preformed expansion joint filler.
38	m joint sealer.
5	sq.m 3mm thick preformed bearing pad shims.
63.62	m railing (deep beam rail with steel tubular back-up, steel posts and bolts).
28	cu.m porous backfill.
18	cu.m asphalt concrete (70-85 or AC-20).
13	cu.m asphalt concrete, (70-85 or AC-20).
13	sq.m galvanized steel drip strip.

Total, Structure over 6 Meter Span.

lump	Project Documentation.
lump	Field Office.
lump	Premium for Contract Performance Bond and for Payment Bond.
lump	Construction Layout Stakes.
lump	Maintaining Traffic.

TOTAL AMOUNT OF THE BID.

APPROXIMATE UNIT QUANTITIES
PER-188-03.84

ROADWAY

Quantity	Unit and Description
lump	clearing and grubbing.
5,054	sq.m subgrade compaction.
1	tonne calcium chloride.
20	cu.m water.
17.7	m pipe removed over 460 mm.
lump	structure removed.
23	sq.m sidewalk removed.
27,151	cu.m excavation not including embankment construction.
26,984	cu.m embankment.
1,140	cu.m embankment, using granular material or rock, as per plan.
50	cu.m traffic compacted surface, Type A or B.
50	cu.m traffic compacted surface, Type C.
160.02	m guard rail, Type 5.
4	each anchor assembly.
8	each guard posts.
27	sq.m 100 mm concrete walk.

Total Roadway.

EROSION CONTROL

7	sq.m riprap, using 150 mm reinforced concrete slab.
71	cu.m rock channel protection, Type A.
258	cu.m rock channel protection, Type B.
20,207	sq.m seeding and mulching.
1.83	tonne commercial fertilizer (12-12-12).
9.17	tonne agricultural liming.
801	sq.m sodding.

Total Erosion Control.

DRAINAGE

50	m 150 mm conduit, Type B.
30	m 150 mm conduit, Type C.

DRAINAGE (cont.)

Quantity	Unit and Description
30	m 150 mm conduit, Type E.
42	m 150 mm conduit, Type F.
50	m 200 mm conduit, Type B.
30	m 200 mm conduit, Type E.
30	m 200 mm conduit, Type F.
124.4	m 310 mm conduit, Type B.
24.2	m 310 mm conduit, Type C.
38.6	m 310 mm conduit, Type D.
21.9	m 380 mm conduit, Type D.
4.4	m 460 mm conduit, Type C.
9.6	m 460 mm conduit, Type D.
17.4	m 460 mm conduit, Type D, 707.01.
45.4	m 690 mm conduit, Type C.
4.6	m 1070 mm conduit, Type C, 706.02.
38	m 1220 mm conduit, Type B, 706.02 Class III or 707.13.
42	m 5050 mm x 3070 mm conduit, Type A, 707.03 (3.51 mm - 4.27 mm), as per plan.
1	each manhole reconstructed to grade.
1	each catch basin No. 2-2-B.
1	each catch basin No. 2-5.
3	each catch basin No. 3-A.
1	each catch basin No. 5.
21.4	cu.m concrete masonry.
540.4	m 150 mm deep pipe underdrains.
3	m aggregate drains for springs, as per plan.
50	m 150 mm unclassified pipe underdrains 707.01 Type III or 707.12, as per plan.

Total Drainage.

PAVEMENT

Quantity	Unit and Description
123	m curb, Type 6.
570	cu.m bituminous aggregate base: 702.01 (70-85 or AC-20); or 702.09, RT-11 or RT-12.
378	cu.m aggregate base.
225	cu.m asphalt concrete (70-85 or AC-20).
150	cu.m asphalt concrete (70-85 or AC-20).

PAVEMENT (cont.)

Quantity	Unit and Description
20	cu.m asphalt concrete (driveways) (70-85 or AC-20).
3,182	liters bituminous prime coat: 702.09, RT-2 or RT-3; 702.02 MC-30 or MC-70; or 702.03 Primer 20.
1,851	liters seal coat bituminous material: 702.02, MC-800 or MC-3000; 702.03, CBAE 800; 702.04, RS-1, RS-2, or CRS-2; or 702.09 or RT-10.
10	cu. m seal coat cover aggregate, No. 8.
	Total Pavement.
Lump	Project Documentation.
Lump	Field Office.
Lump	Premium for Contract Performance Bond and for Payment Bond.
Lump	Construction Layout Stakes.
Lump	Maintaining Traffic.
	TOTAL AMOUNT OF THE BID.

Chapter 4 -- Phase 3. Public Use and Adaptation.

Evaluation of motorist response to metric informational signs which have been installed on Interstate highways in Ohio.

4.1 Introduction

Although the Ohio Department of Transportation (ODOT) will face many internal problems during the conversion period, from the customary American system to the metric system, it recognizes the fact that Ohio's motorists will face some special problems while traveling the highway system. With all signing containing metric units rather than English units, the motorist's primary problem will be to develop the relationship between the metric unit of length, the metre or kilometre, and other parametres involving distance until all conscious or subconscious reference to the mile as a unit of measure is removed.

In recognition of this fact, ODOT has initiated a program to help prepare the motorist for the probable transition to the metric system. This program involved the erection of 33 destination signs, providing the distance measurement in both miles and kilometres, alongside Interstate highways in Ohio.

As part of this effort, twenty-two of these signs were installed at various locations throughout Ohio on Interstate 75, north of Dayton (4 signs), Interstate 70 (6), Interstate 71 (8) and Interstate 77 (4). Two signs, one in each direction of travel, were installed between all major metropolitan areas early in 1973. Each sign was designed and placed such that one of the distance measurements, either the number of miles or the number of kilometres, is either "200", "100", or "50". In this way the precise numerical relationship of 1.00 mile equalling 1.61 kilometres, or 1.00 kilometres equalling 0.62 miles, is presented to the motorist in as clear a fashion as possible. Note: Photographs of these signs have been published in this research project's "Interim Report" and

are not reproduced herein.

With the belief that the provision of dual-unit destination signing will be of major assistance in each motorist's effort to learn the spatial relationships involving the kilometre, the Department replaced all existing destination signing (11 signs) on Interstate 75 between Dayton and Cincinnati with dual-unit destination signing in August, 1973. The purpose of this extensive use of the dual-unit signing is to provide the motorist with a continual reference to the general relationship between the two units of measurement.

However, with this extensive signing system, no attempt was made to design and locate these signs so as to provide an easily understood relationship, i.e. 100 mi. equals 161 km. These signs merely replace existing signs at the same location and the destination distances are shown in both customary (miles) and metric (kilometres) units. This fact then raises the question as to whether or not this lack of the obvious reference to the precise numerical relationship will enhance, degrade, or have no effect on the motorist's ability to comprehend and apply this relationship as quickly and as smoothly as possible.

Figure 7 is a map of Ohio showing the general location of each of the twenty-two dual-unit destination signs between the major metropolitan areas and the section of Interstate 75 on which all eleven existing destination signs were converted to dual-unit destination signs. Figures 8 and 9 contain typical drawings for the signs used between all major metropolitan areas and on Interstate 75 between Dayton and Cincinnati respectively.

4.2 Objectives of Phase 3

The objectives of the Phase 3 study are two-fold:

(1) To determine the change over time in the public awareness, acceptance, and general understanding of the metric system and to determine the interrelationships between these factors and,

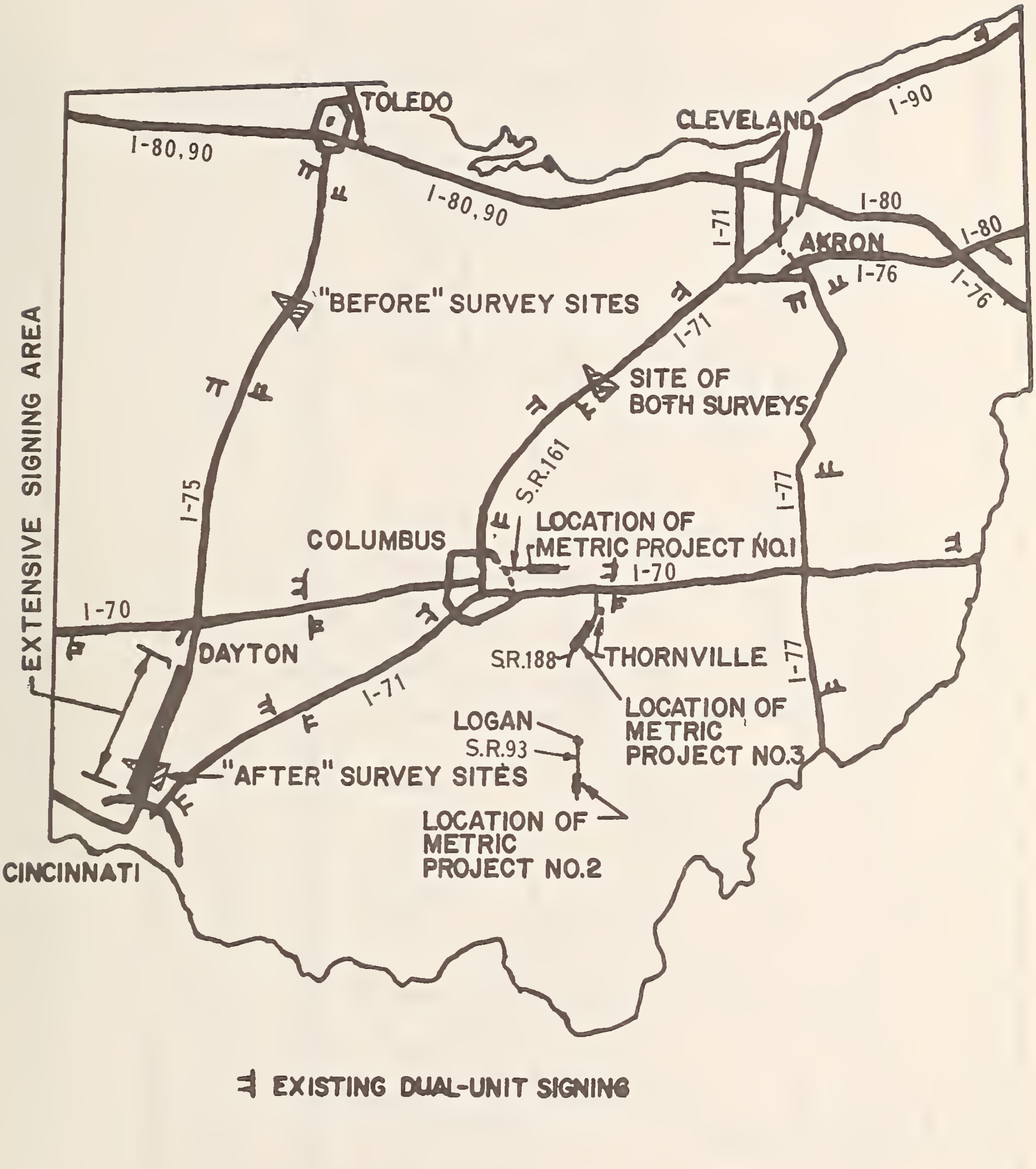


Figure 7. Locations of dual-unit destination signs, motorist survey areas and the three metric projects.

Figure 8. Typical Sign for Placement Between Major Metropolitan Areas

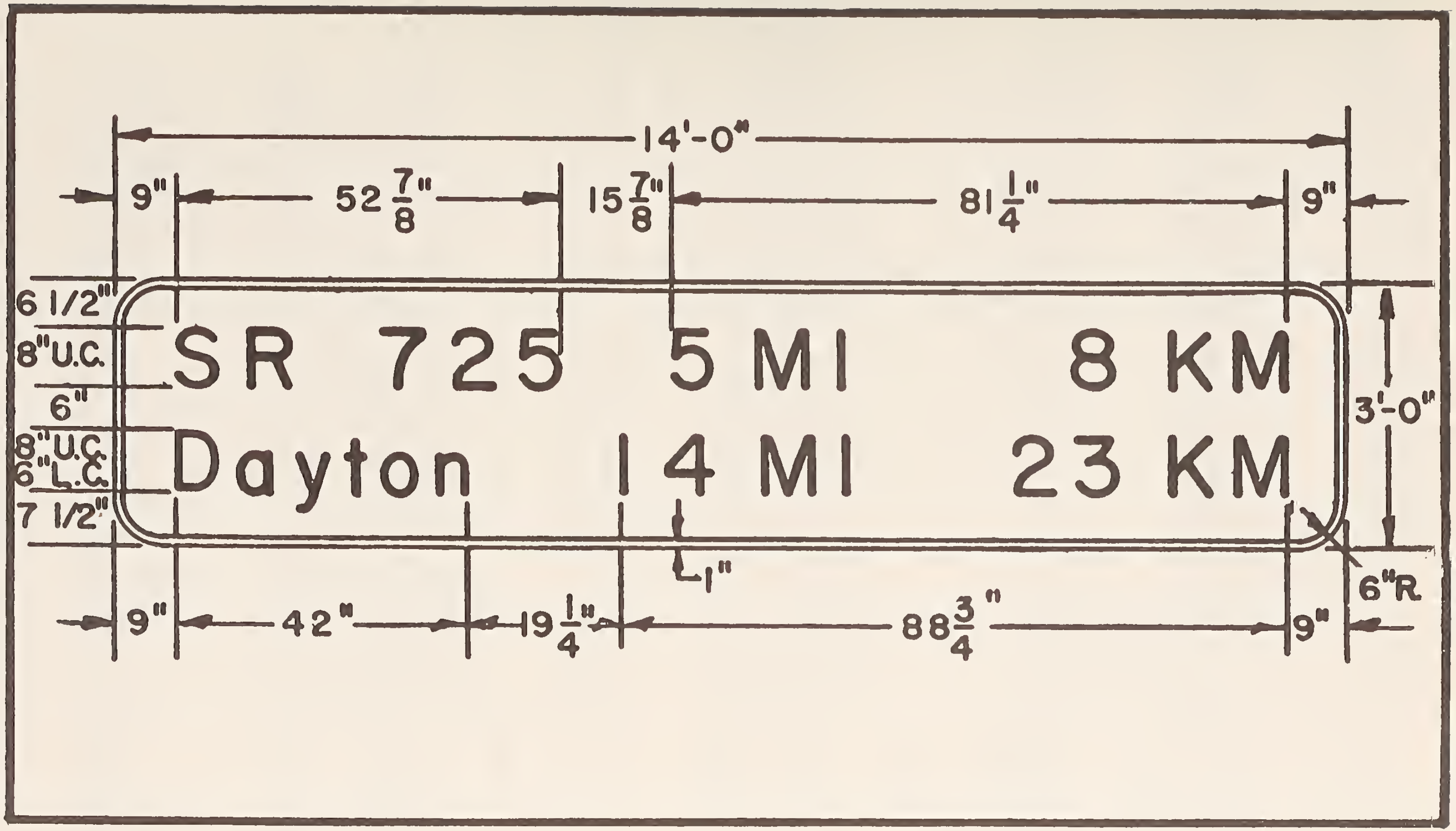


Figure 9. Typical Sign for Installation on I-75 Between Cincinnati and Dayton

(2) To determine the effect of the extensive dual-unit signing system on the change in the public's awareness, acceptance, and general understanding of the metric system.

The objectives of this study were attained by analyzing the variation in motorist's responses to questionnaires administered during the summer of 1973 and the spring and summer of 1974.

The questionnaire proposed for use in this study was designed to be administered verbally by a Department representative. Figure 10 is a copy of the questionnaire used in this study.

4.3 Scope of Study

This report contains an analysis of the motorist's responses to 2,000 questionnaires administered in September, 1973 (the Before survey), 1,440 questionnaires administered in April, 1974 (the first After survey), and 1,570 questionnaires administered in August, 1974 (the second After survey).

The results presented in this report are final results and thus reflect the entire experience to date.

4.4 Study Procedures

The basic experimental design for this study is a "Before vs. After: Study vs. Control" design. The questionnaires were administered at the two rest areas on the section of I-75 with the extensive dual-unit signing system (study site) and at the two rest areas on I-71 between Mansfield and Ashland (control site), both before and after the installation of the extensive dual-unit signing system.

Analysis of the "Before vs. After" data at the control sites provides a measure of the effect of the passage of time on motorist's responses. Analysis of the "Study vs.

SURVEY QUESTIONNAIRE

DATE________ __ INITIALS _________ LOCATION___________

Hello, My name is____________________and I am helping the Ohio Department of Transportation conduct a survey of driver awareness of highway features. Would you care to participate in this survey by answering the following nine questions which will require about three minutes of your time?

1. What is your city and state of residence?
   City _____________________ State ___________________

2. How often do you travel this section of highway?
   _____________ times per day ☐ wk ☐ mo. ☐ yr. ☐

3. Which is greater in length, one mile or one kilometer?
   mile_____________ kilometer______________

4. Which is heavier, one ounce or one gram?
   ounce_____________ gram_______________

5. Approximately ______mile)s) before this rest area there was a sign which gave the distance to _________________, Can you tell me that distance in miles? ________________ miles

6. Suppose it is 10 miles from here to your home. How far is that in kilometers? ______________km.

7. Have you heard of the pending change from U.S. to metric units which is being considered by Congress?
   Yes_________ No__________

8. Are you in favor of changing to the metric system?
   Yes_________ No _________ No Opinion_________

9. The Ohio Department of Transportation has taken the initiative in the conversion to the metric system by providing both U.S. and metric units on some of its destination signing on the Interstate. Do you find this signing to be helpful _______, not helpful___________, or confusing___________ in making the transition to the metric system?

Thank you for participating and have a nice day!

Figure 10. Sample Questionnaire

Control" data from the before to the after period provides a measure of the effect of the extensive dual-unit signing system as an addition to the selected use of the dual-unit signs which make the conversion factor more obvious.

During the before survey (August, 1973), it was not feasible to administer the questionnaire at the study site, as that section of I-75 was under construction as a part of the Interstate Upgrading Program. In lieu of surveying at the study site, an alternate study site (the two rest areas on Interstate 75 between Lima and Findlay) was chosen for the before survey. Since both pairs of rest areas are on I-75, it is reasonable to assume that the pattern of responses at the two study sites are equal in the before study period and since the objective of the before study is to establish the base levels of the measured parameters, the integrity of the "Before vs. After: Study vs. Control" experimental design is upheld. Figure 7 shows the location of the rest areas where the questionnaire were administered.

In order to adequately ascertain the public reaction to the ODOT Metrication efforts, it was felt that the following items would have to be considered:

(1) public awareness of metrication,
(2) public acceptance of the transition to the metric system,
(3) the relationship between the public's awareness of metrication and its acceptance of the transition to the metric system,
(4) public understanding of the metric system,
(5) the relationship between the public's understanding of the metric system and its acceptance of the transition to it,
(6) the ability of the motorist to use the proper U.S. to metric conversion factor for distance,
(7) the ability of the motorist to recall a specific sign message, and
(8) public opinion of dual-unit destination signing as an aid in making the transition to the metric system.

The remainder of the report is structured so as to present demographic information which is general in nature, followed by sections treating each of the eight previous areas of interest.

4.5 Analysis and Results

The first item of general interest obtained from the surveys is a description of the types of travel experienced at the study and control sites. Questionnaires were administered only to drivers of passenger cars and similar vehicles. No commercial vehicle drivers were interviewed. It should be recognized that due to the method of administering questionnaires (at rest areas), few short trips were surveyed. Rather, those drivers surveyed were "long" trip drivers. Figure 11 shows the proportion of drivers at each site that resided in or out of Ohio. It can be noted from this figure that Interstate 75 carries more out of state drivers than does Interstate 71.

In addition to the pattern of responses to the first question on the questionnaire just presented, the responses to the remaining eight questions are compiled and presented in Figures 12 through 19.

The next item of interest to the study involves the frequency of usage. As the motorist's ability to understand the relationship between customary and metric units is dependent on the frequency of exposure (on the highway or elsewhere) to the relationship, the study was designed to examine the frequency of travel for each driver through the survey sites. An arbitrary partition of responses was made as follows:

- Frequent usage represents the case where the driver used the facility at least two times per month.

- Infrequent usage represents the case where the driver used the facility less than two times per month.

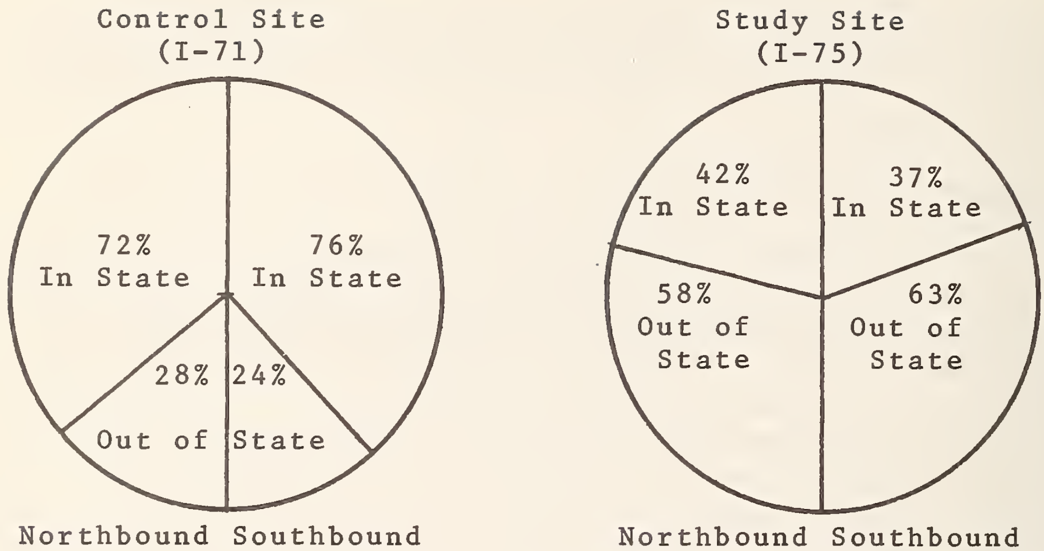


Figure 11. Proportion of Drivers Interviewed By State of Residence (All data).

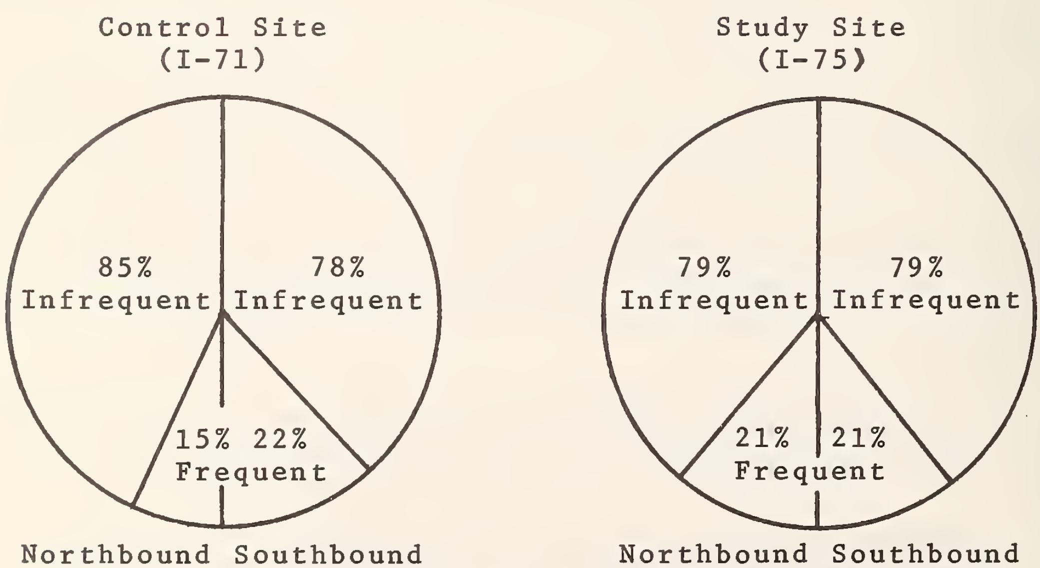


Figure 12. Proportion of Drivers Interviewed By Frequency of Travel (All Data).

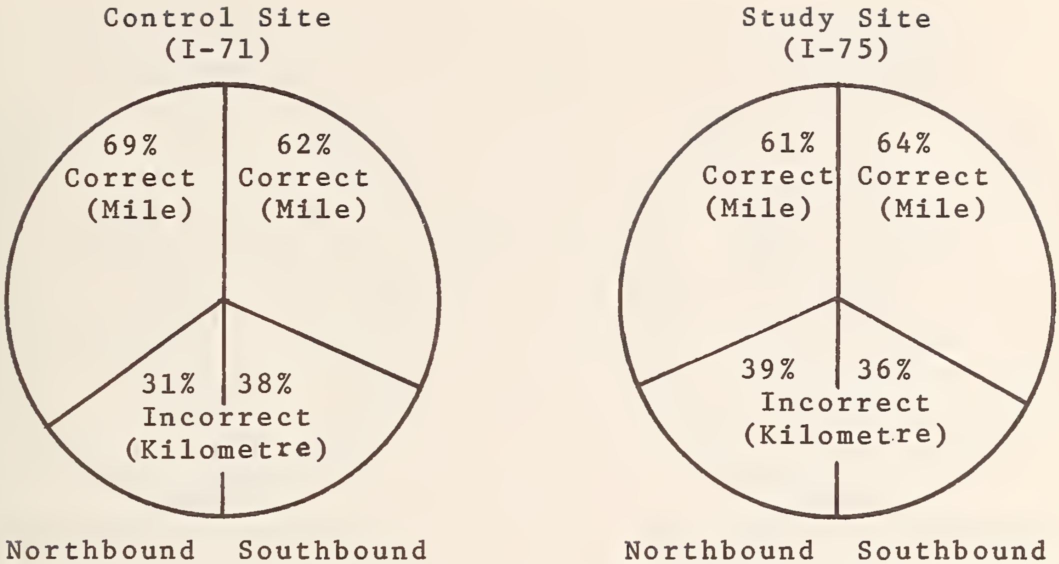


Figure 13. Proportion of Drivers Interviewed By Understanding of Mile-Kilometre Relationship (Which is Greater in Length-One Mile or One Kilometre?)

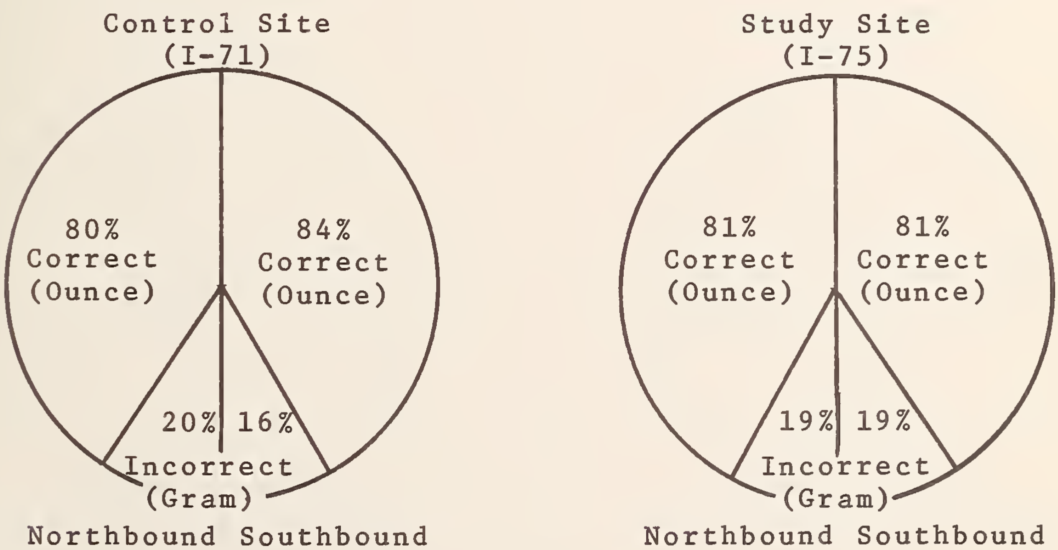


Figure 14. Proportion of Drivers Interviewed By Understanding of Ounce-Gram Relationship (Which is Heavier, one ounce or one gram?)

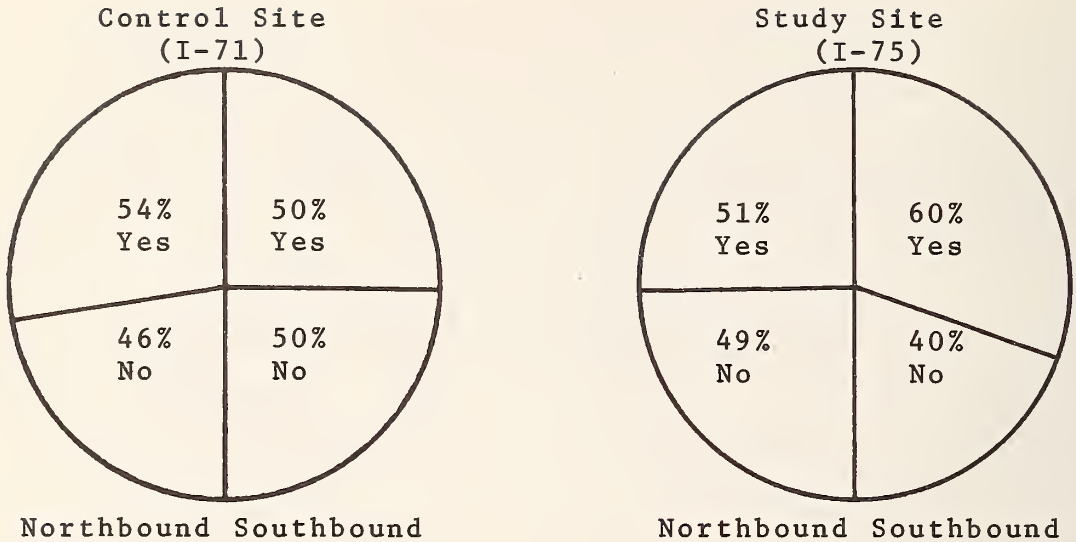


Figure 15. Proportion of Drivers Interviewed by Their Observation and Memory of Latest Destination Sign.

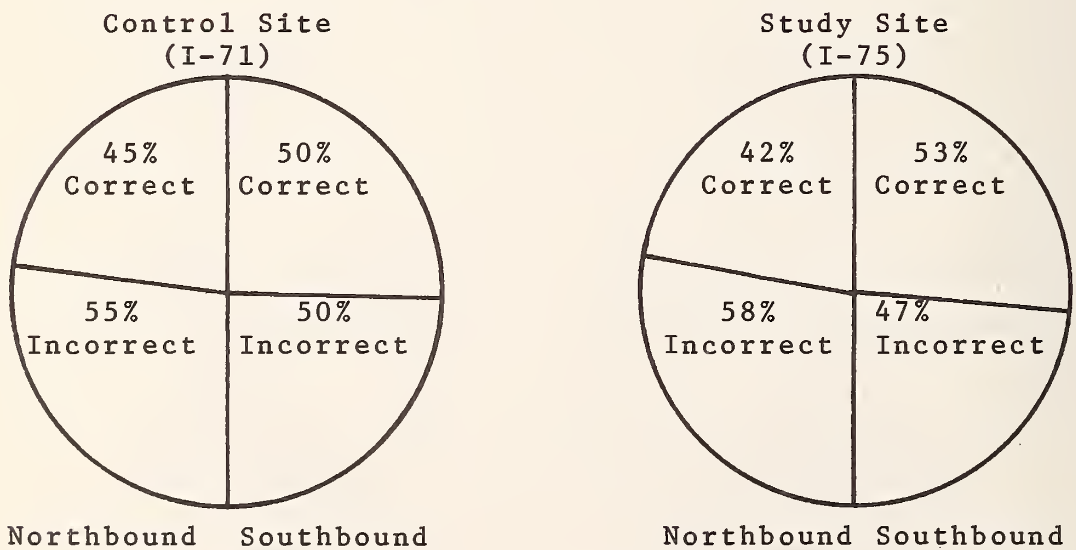


Figure 16. Proportion of Drivers Interviewed by their Knowledge and Proper Use of Mile-Kilometre Conversion Factor.

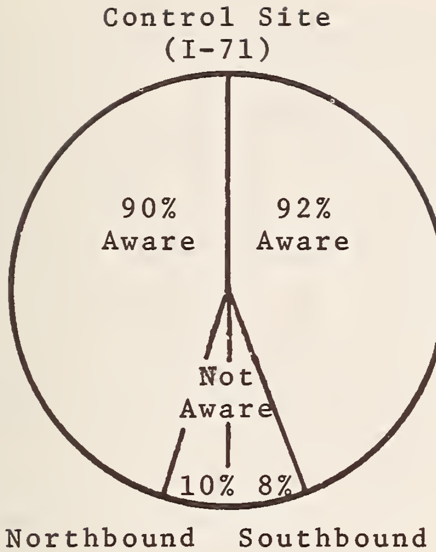


Figure 17. Proportion of Drivers Interviewed by Their Awareness of the Pending Change to the Metric System.

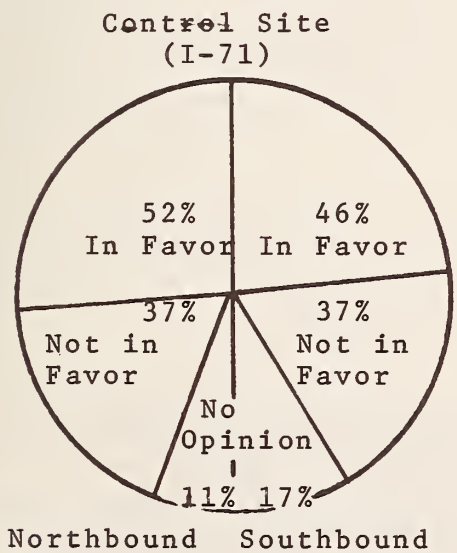


Figure 18. Proportion of Drivers Interviewed by Their Acceptance of the Metric System (Are You In Favor of Changing to the Metric System?)

As the purposes of this study are (1), to determine the change over time in the measured parameters (Before vs. After analysis) and (2), to determine the effect of the extensive signing system on the measured parameters (Study vs. Control analysis) it is necessary to examine the frequency of use for both situations. Table 21 shows the results of a Chi-Square Contingency Test conducted on all the study data to determine if there is a significant difference in the frequency of use between the study and control sites (Before vs. After analysis). The results of this test indicate that there is no difference in the frequency of use between the study and control sites for this case. Thus, for presentations of the change over time in measured parameters (Objective 1), no distinction of frequency of use will be made.

In order to determine the effect of the extensive dual-unit signing system, the second after survey data was analyzed by frequency in a similar manner. Table 22 shows the results of this test using the second after survey data. The results of this test indicate that there is a difference in the frequency of usage between the study and control sites (the control site had a lower proportion of frequent users than expected) for this case. Therefore, results concerning the effect of the extensive signing system on the measured parameters (Objective 2) will be presented for both frequent and infrequent users.

For the remainder of the analysis, both the change in parameters over time and the effect of the extensive dual-unit signing system on these parameters will be analyzed for each of the eight items previously stated.

The first item of concern is the public awareness of metrication. Figure 20 shows the proportion of drivers interviewed who were aware of the pending change to the metric system for all three survey periods. It can be noted from this figure that the proportion of drivers aware of the pending change has experienced a slight decrease over the duration of the study. However, this decrease is not felt to be significant. The effect of the extensive signing

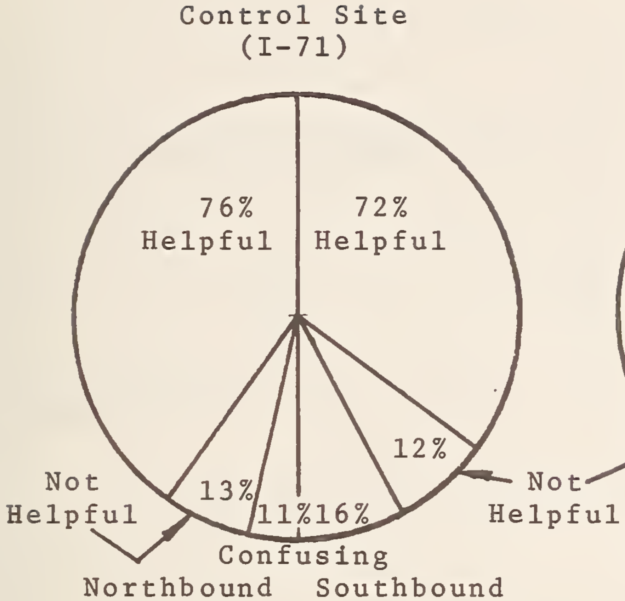


Figure 19. Proportion of Drivers Interviewed by Their Evaluation of the Current Metric Destination Signs.

Table 21. Chi-Square Test For Difference in Frequency of Use (All Study Data - Before vs. After Analysis)

Frequency of Use	Study Site	Control Site
Frequent	620 (595)	392 (417)
Infrequent	2299 (2324)	1652 (1627)

( ) = Expected cell Frequency

Hypothesis: There is no difference in the frequency of use between study and control sites.

$X^2 = 3.202$ $X^2_{0.05} = 3.841$

Result: Accept Hypothesis

Table 22. Chi-Square Test for Differences in Frequency of Use (After II Survey Date - Study vs. Control Analysis).

Frequency of Use	Study Site	Control Site
Frequent	254 (204)	88 (138)
Infrequent	666 (716)	537 (487)

(   ) = Expected cell Frequency

Hypothesis: There is no difference in frequency of travel between study & control sites.

$X^2 = 38.996$ $X^2_{0.05} = 3.841$

Result: Reject Hypothesis

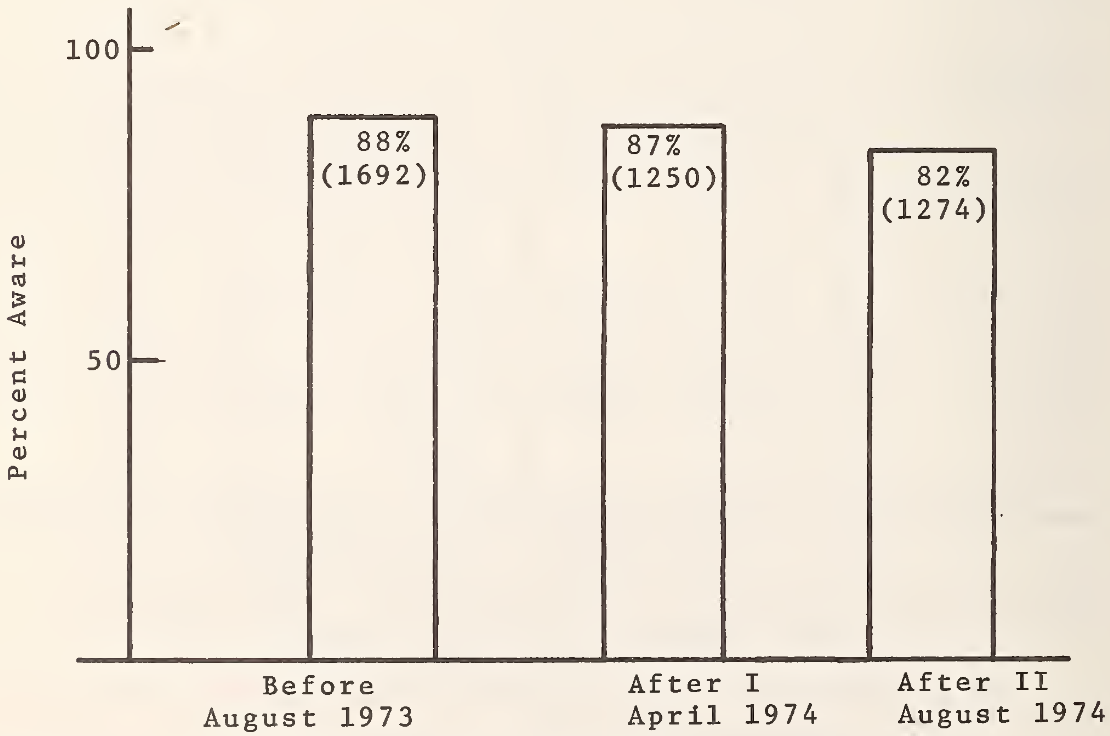


Figure 20. Percentage of Drivers Interviewed Who Were Aware of Metrication.

system on the public's awareness of the pending change was examined to determine if a difference in awareness existed between study and control sites. Tables 23 and 24 show the results of the Chi-square Tests, for frequent and infrequent users respectively, used to determine the effect of the extensive signing system. Both tests indicate that a difference in awareness existed between the study and control sites. The fact that, for both types of users, the control site had a higher than expected proportion of drivers who were aware of the pending change implies that the extensive signing system may have had a diminishing effect on people's awareness.

The second item of consideration involves the public acceptance of a transition to the metric system. In order to determine the change in acceptance over time, the data from the control site (including the before study site) was analyzed over time. Figure 21 displays the results of this analysis. As can be noted from this figure, there has been a slight decrease in the percentage of motorists who are in favor of changing to the metric system. Although the larger no opinion response during the first after survey appeared to indicate increased confusion regarding a transition, the responses appear to be attaining a stable position of being almost evenly divided pro and con.

The third item of concern is the relationship between the public's awareness of the pending change and its acceptance of a transition to the metric system. In general, this relationship is portrayed by the survey responses at the control site. Table 25 shows the results of the Chi-Square Test conducted on the control data (including the before study site) to ascertain this relationship. The results of this test indicate that a relationship between awareness of the pending change and acceptance of the transition does exist. An examination of the data in Table 25 reveals a disproportionately high frequency of "Aware-In Favor" responses and disproportionately low frequencies of "Aware-Not in Favor" and "Aware-No Opinion" responses. This response pattern implies that as the driver becomes more aware of the metric system, a transition to the metric

Table 23. Chi - Square Test For Difference in Awareness of Metrication Between Study and Control. (After II Survey Data - Study vs Control Analysis - Frequent Travelers Only).

Awareness of Metrication	Study Site	Control Site
Aware	179 (189)	58 (48)
Not Aware	64 (54)	4 (14)

( ) = Expected Cell Frequency

Hypothesis: There is no difference in the frequent travelers' awareness of metrication between study and control sites.

$X^2 = 11.607 \quad X^2_{0.05} = 3.481$

Result: Reject Hypothesis

Table 24. Chi-Square Test For Difference in Awareness of Metrication Between Study and Control Sites. (After II Survey Date - Study vs Control Analysis - Infrequent Travelers Only)

Awareness of Metrication	Study Site	Control Site
Aware	541 (573)	488 (456)
Not Aware	144 (112)	57 (89)

( ) = Expected cell frequency

Hypothesis: There is no difference in the infrequent travelers' awareness of metrication between study and control sites.

$X^2 = 24.681 \quad X^2_{0.05} = 3.481$

Result: Reject Hypothesis

Table 25. Chi-Square Test For General Relationship Between Awareness and Acceptance (All Control Data)

Acceptance of Transition	Aware	Not Aware
In Favor	948 (888)	37 (97)
Not In Favor	677 (693)	92 (76)
No Opinion	227 (271)	74 (30)

( ) = Expected Cell Frequency

Hypothesis: There is no relationship between awareness of the change and acceptance of transition to the metric system.

$X^2 = 116.582$ $X^2_{0.05} = 5.991$

Result: Reject Hypothesis

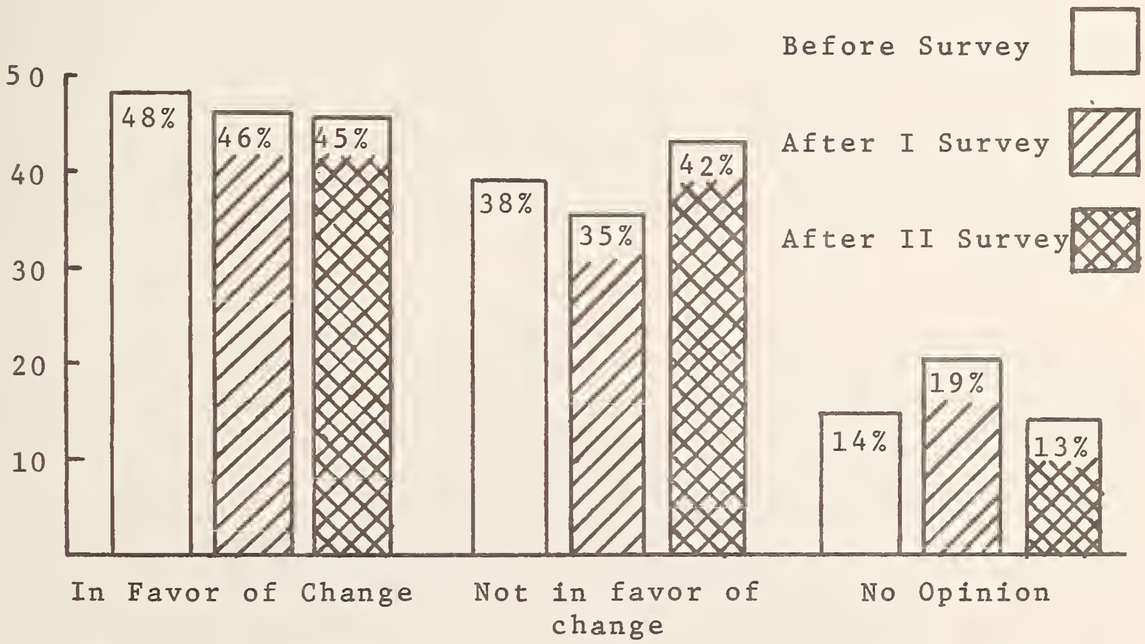


Figure 21. Percent of Drivers Interviewed At Control Site By Acceptance of Change To Metric System (Before vs After I vs After II Analysis)

system becomes more acceptable to him. Since these results substantiate similar interim results, it is obvious that thorough public awareness of the metric system must preceed public acceptance of the system. Thus, it is apparent that a thorough public information effort is a prerequisite for an efficient transition to the metric system.

In order to determine the effect of the extensive signing system on public awareness and acceptance of the metric system, Chi-Square Tests were conducted on the second after survey data from the study site. The results of these tests, for frequent and infrequent users, respectively, are shown in Tables 26 and 27 These tests indicate a relationship between awareness and acceptance similar to that displayed by the control data. Therefore, the extensive system has no effect on the public's relationship between awareness and acceptance of the metric system.

Due to the nature of the remaining analyses, it was necessary to partition the responses into two groups, based on the consistency of the responses to questions 3 and 6 on the questionnaire. Those questionnaires which contained consistent responses (e.g. a mile is longer than a kilometre (Q. 3) and there are more than 10 kilometres in 10 miles (Q. 6) were retained for further analysis. Those questionnaires which contained inconsistent responses (e.g. a mile is longer than a kilometre and there are less than 10 kilometres in 10 miles) were dropped from all remaining analyses.

The fourth item of interest concerned the public understanding of the basic relationships between the customary and metric systems. Two relationships were considered in this analysis: distance (mile vs. kilometre) and weight (ounce vs. gram). The general understanding of these relationships was determined by analyzing the study and control data over time. Table 28 shows the proportion of correct responses to the questions concerning the distance and weight relationships for both survey sites. It can be noted from this table that both increases and decreases in understanding occurred. Of primary concern to ODOT is the

Table 26. Chi-Square Test for Relationship Between the Frequent Traveler's Acceptance of Metrication and His Awareness of Metrication (After II Study Date - Frequent)

Acceptance of Metrication	Aware	Not Aware
In Favor	103 (80)	6 (29)
Not In Favor	61 (83)	53 (31)
No Opinion	14 (15)	7 (6)

( ) = Expected Cell Frequency

Hypothesis: There is no relationship between the frequent traveler's acceptance of metrication and his awareness of metrication.

$X^2 = 46.531$ $X^2_{0.05} = 5.991$

Result: Reject Hypothesis

Table 27. Chi-Square Test for Relationship Between The Infrequent Traveler's Acceptance of Metrication and His Awareness of Metrication (After II Study Date - Infrequent)

Acceptance of Metrication	Aware	Not Aware
In Favor	244 (203)	11 (52)
Not In Favor	223 (248)	88 (63)
No Opinion	37 (53)	29 (13)

( ) = Expected cell Frequency

Hypothesis: There is no relationship between the infrequent traveler's acceptance of metrication and his awareness of metrication.

$X^2 = 77.570$ $X^2_{2.05} = 5.991$

Result: Reject Hypothesis

pattern of responses to the distance relationship. Although the differences in correct responses are small, fewer drivers at the study site gave correct responses.

Tables 29 and 30 show the results of Chi-Square Tests conducted to determine if there was a difference in the number of correct responses to the distance relationship between the study and control sites for frequent and infrequent users respectively. The results of these tests indicate that there is no difference for frequent users but that there is a difference for infrequent users. A review of Table 30 reveals that fewer drivers than expected at the study site gave correct responses. Therefore, the extensive signing system has no effect on understanding for frequent users but has a detrimental effect on infrequent users.

The fifth item of interest concerns the relationship between public understanding of and acceptance of the metric system. The general relationship between understanding and acceptance is determined by analyzing all the control data. The results of the Chi-Square Test, Table 31, used to determine this relationship indicate that a relationship between understanding and acceptance exists. The pattern of responses in Table 31 show that the better drivers understand the relationships between customary and metric units, the more they are in favor of changing to the metric system. A similar test was conducted on the second after survey data for the study site, Table 32. The results of this test are identical to those at the control site. Therefore, it is apparent that understanding is required for acceptance of the metric system and that the extensive signing system has no effect on this relationship.

The sixth item of concern is the ability of the motorist to use the proper U.S. to metric conversion factor for distance. The general ability is determined by examining all control data over time, as shown in Table 33. Although the data presented in Table 33 is subdivided by frequency of use, there is no statistical difference in frequency for control data. This division was made to show the effect of exposure to the signs displaying the precise

Table 28. Correct Responses Concerning Distance and Weight Relationships (Control *vs* Study)

Distance Relationship		
Survey	Control	Study
Before August, 1973	80%	---*
After I April, 1974	77%	75%
After II August, 1974	83%	77%
Weight Relationship		
Survey	Control	Study
Before August, 1973	73%	---*
After I April, 1974	79%	81%
After II August, 1974	81%	78%

*Included in Control Data

Table 29. Chi-Square Test for Difference in the Frequent Traveler's Knowledge of Distance Relationship Between Study and Control Site (After II Data-Frequent)

Distance Relationship	Study	Control
Correct	108 (110)	44 (42)
Incorrect	19 (17)	5 (7)

( ) = Expected cell frequency

Hypothesis: There is no difference in the Frequent Traveler's knowledge of the distance relationship between study and control sites

$X^2 = 0.938$ $X^2_{0.05} = 3.841$

Result: Accept Hypothesis

Table 30. Chi-Square Test for Difference in the Infrequent Traveler's Knowledge of Distance Relationship Between Study and Control Site (After II Data - Infrequent)

Distance Relationship	Study	Control
Correct	.270 (280)	194 (184)
Incorrect	92 (82)	43 (53)

( ) = Expected cell frequency

Hypothesis: There is no difference in the infrequent traveler's knowledge of the distance relationship between study and control sites.

$X^2 = 4.007$ $X^2_{0.05} = 3.841$

Result: Reject Hypothesis

Table 31. Chi-Square Test for Relationship Between The Traveler's Understanding of the Metric System and His Acceptance of it (All Control Data - including Study Before)

Responses to both Relationship Questions	Acceptance of Metrication		
	In Favor	Not In Favor	No Opinion
Both Correct	673 (554)	256 (347)	114 (142)
One Correct	136 (188)	164 (119)	55 (48)
None Correct	34 (101)	109 (63)	47 (26)

( ) = Expected cell frequency

Hypothesis: There is no relationship between the traveler's understanding of the metric system and his acceptance of metrication.

$X^2 = 182.362$ $X^2_{0.05} = 9.488$

Result: Reject Hypothesis

Table 32	Chi-Square Test For Relationship Between The Traveler's Knowledge of The Metric System and His Acceptance of The Transition To The Metric System (Study After II Data)		
Responses to Both Relationship Questions	Acceptance of Metrication		
	In Favor	Not In Favor	No Opinion
Both Correct	205 (162)	99 (132)	15 (25)
One Correct	33 (60)	71 (48)	13 (9)
None Correct	12 (23)	33 (23)	10 (4)

( ) = Expected cell frequency

Hypothesis: There is no relationship between the traveler's understanding of the metric system and his acceptance of transition to that system.

$X^2 = 71.102$ $\quad$ $X^2_{0.05} = 9.488$

Result: Reject Hypothesis.

Table 33. Ability Of Motorists To Use Proper English to Metric Conversion (Control Data)

Frequent Usage		
Survey	Correct	Incorrect
Before August 1973	62%	38%
After I April 1974	71%	29%
After II August 1974	83%	17%

Infrequent Usage		
Survey	Correct	Incorrect
Before August 1973	59%	41%
After I April 1974	51%	49%
After II August 1974	65%	35%

relationship between the systems. In general, the ability of motorists to convert properly has increased over the time of the surveys, with frequent users showing a higher ability than infrequent users.

In order to determine the effect of the extensive signing system on the motorist's ability to make the proper distance conversion, Chi-Square Tests were conducted on the second after survey data. The results of these tests, as presented in Tables 34 and 35 for frequent and infrequent users, respectively, indicate no difference in conversion ability between study and control sites. Thus, the extensive signing system has no effect on the motorist's ability to make the proper distance conversion.

The seventh item of interest is the ability of the motorist to recall specific sign messages. In all cases, the motorist was asked to recall the mileage shown on the second line of the dual-destination sign which immediately preceeded the rest area. Table 36 displays the proportion of correct responses for study and control sites, subdivided by frequency of use. A review of Table 36 reveals mixed results; however, an overall increase in the motorist's ability to recall specific messages occurred over time. Although not definitely established, there is an indication that the study site experienced better recall ability than the control site, at least for infrequent users. This may be due to the uniqueness of the signs at the study sites. However, the lack of a consistent pattern precludes making definite conclusions regarding this item.

The eighth and final item of interest concerns the public's opinion of dual-unit destination signing as an aid in making the transition to the metric system. In general, this opinion can be ascertained by examining the control data over time. Table 37 shows the opinions of the motorists surveyed. As can be noted from this table, the majority of the motorists surveyed feel that ODOT use of dual-unit destination signing is helpful in making a transition to the metric system. A decrease in the proportion responding "Helpful" was noted between the before and first after period. However, the attitudes appear to have stabilized.

Table 34. Chi-Square Test For Relationship Between the Frequent Traveler's Ability to Properly Make the English to Metric Conversion and the Interview Site (After II Survey Data)

Able To Make Conversion	Study	Control
Yes	98 (102)	43 (39)
No	40 (36)	9 (13)

( ) = Expected cell frequency

Hypothesis: There is no relationship between the frequent traveler's ability to properly make the Metric conversion and the interview site.

$X^2 = 2.242$ $X^2_{0.05} = 3.841$

Result: Accept Hypothesis

Table 35. Chi-Square Test For Relationship Between The Infrequent Traveler's Ability To Properly Make The English To Metric Conversion And The Interview Site. (After II Survey Data)

Able To Make Conversion	Study	Control
Yes	186 (195)	152 (143)
No	135 (126)	83 (92)

( ) = Expected cell frequency

Hypothesis: There is no relationship between the infrequent traveler's ability to properly make the English to Metric conversion and the interview site.

$X^2 = 2.505$ $X^2_{0.05} = 3.841$

Result: Accept Hypothesis

Table 36. Ability of Motorists To Recall A Specific Sign Message (Study Vs. Control, Divided By Frequency - Over Time)		
Frequent Usage		
Survey	% Correct	
	Control	Study
Before Survey (August 1973)	47%	41%
After I Survey (April 1974)	45%	33%
After II Survey (August 1974)	51%	65%
Infrequent Usage		
Before Survey (August 1973)	45%	55%
After I Survey (April 1974)	42%	48%
After II Survey (August 1974)	54%	57%

Table 37. Opinion of Dual-Unit Destination Signing as Aid in Transition to Metric System

Survey	Helpful	Not Helpful	Confusing
Before Survey (August, 1973)	84%	7%	9%
After I Survey (April, 1974)	74%	13%	13%
After II Survey (August, 1974)	75%	15%	10%

4.6 Summary of Results

In summary, the following results were obtained from the approximately 5,000 drivers interviewed during the three surveys:

1) Approximately 86 percent of the drivers interviewed were aware of the pending change to the metric system being considered by Congress. This percentage decreased slightly over time and the drivers interviewed at the extensive signing system site (study site) showed lower awareness of the pending change.
2) The percentage of drivers who are in favor of changing to the metric system decreased over time. At the time of the second after survey, drivers were about evenly divided (45 percent in favor, 42 percent not in favor, with 13 percent giving no opinion).
3) There is a definite relationship between public awareness of and acceptance of a transition to the metric system. As a driver becomes more aware of the metric system, he accepts it more readily. This relationship is also present at the site of the extensive signing system, but may not be due to that system.
4) Approximately 80 percent of the drivers surveyed at the control site and 76 percent at the study site understood the basic distance relationship (miles vs. kilometres). Approximately 78 percent of the drivers surveyed at the control site and 80 percent at the study site understood the basic weight relationship (ounce vs. gram). These proportions were relatively unaffected by time. Of primary concern to ODOT is the distance relationship. In this regard, the extensive signing system has no effect on understanding for frequent users but has a small detrimental effect on infrequent users.
5) There is a relationship between public understanding of and acceptance of the metric system. As the motorists understand the basic relationships between English and Metric units, they accept the metric system more readily.

6) A majority of the motorists interviewed were able to use the proper distance conversion from miles to kilometres. This proportion increased more rapidly over time for frequent users of the highway than for infrequent users. The extensive signing system has no effect on a motorist's ability to use the proper distance conversion.

7) No pronounced effect upon the motorist's ability to recall specific sign messages was noted in the survey.

8) Approximately 77 percent of the highway users interviewed felt that ODOT use of dual-unit destination signing is helpful in making a transition to the metric system.

4.7 Conclusions

The following conclusions are based on the results of this study:

1. Motorists are approximately evenly divided on the issue of metrication. The proportion of drivers who are in favor of changing to the metric system has decreased over time, but still maintains a slight lead.
2. The motorists' understanding and awareness of the relationships between the U.S. and metric systems have a direct positive relationship to their acceptance of a change to the metric system.
3. The ability of motorists to use the proper U.S. to metric conversion for distance (mile vs. kilometre) and weight (ounce vs. gram) increased over time.
4. The extensive dual-unit signing system had no beneficial effect on the parameters measured in this study, i.e. awareness, understanding and acceptance. It either had no effect or a small negative effect.
5. A clear majority (75 percent) of the motorists indicated that dual-unit destination signing would be helpful in a transition to the metric system.

Chapter 5 - Phase 4. Public Information

Dissemination of metric information to the public through distribution of a metric package, periodic news releases, correspondence and speeches.

5.1 Metric Package

Recognizing the desirability of informing the general public, the Ohio Department of Transportation decided early in 1973 to accumulate a metric information package and to make this package available, free of cost, to interested people upon request. So far, approximately 3000 of these packages have been distributed with 85% going to teachers, news media representatives and other persons and organizations interested in metrication; and the remainder going to technical persons such as engineers and university professors. These packages are still being distributed upon request.

5.1.1 Original Package

The original package contained the following items:

a. ODOT Director Richley's Statement: This statement was delivered by J. Phillip Richley, Director of the Ohio Department of Transportation to U.S. House of Representatives' Subcommittee on Science, Research and Development of the Committee on Science and Astronautics on March 22, 1973. The statement contains a description of Ohio's Five-Phase work program concerning the introduction of the metric system into the field of highway transportation and a revelation that ODOT had requested of the Federal Highway Administration an administrative grant to be authorized by the Secretary of Transportation that would consider a summary study and report to be made of Ohio's program.

b. "Metric System in Ohio" white paper: This paper was prepared to explain Ohio's interest in metrication and to outline more specifically the five-phase work program.

c. Outlines of Ohio's Metric Projects: These outlines explain in detail Ohio's first two metric projects.

(1) Metric Project No. 1 -- State Route 161. This project is 8.21 kilometres (5.1 miles) of State Route 161 in Licking County. It consisted of resurfacing and overlaying asphalt on an existing two-lane, 7.32 metres (24 ft.) wide, pavement.

(2) Metric Project No. 2 -- State Route 93. This Hocking County project will relocate 1.5 kilometres (0.96 miles) of State Route 93. Included in the project is replacement of a deteriorated stream crossing and elimination of poorly aligned approaches to the bridge.

d. Plans for Metric Project No. 1: Detailed plan sheets (6) for the Licking County S.R. 161 resurfacing and asphalt overlay project were included in the brochure. The original plan sheet size was reduced to a 12" x 18" size for easy inclusion.

e. Plans For Metric Project No. 2: Details of the design of the Hocking County S.R. 93 relocation project outlining the preliminary engineering phase, a discussion of the standards to be used and suggested typical sections were also included in the brochure. These plans were reproduced in an 8-1/2" x 14" size for easy inclusion.

f. Photographs of Metric Signs: These photographs are of two typical destination signs showing the distance measurement to a city in both miles and kilometres.

(1) Sign located on I-71 between Columbus and Cincinnati showing the distance to Cincinnati as 62 miles and 100 kilometres. This was Ohio's and the nation's first metric distance sign.

(2) Sign located on I-71 between Columbus and Cleveland showing the distance to Cleveland as 94 miles and 151 kilometres. Photograph shows sign being erected by a work crew from ODOT.

g. Metric System Guide: This is a small pamphlet printed on both sides of glossy 8-1/2" x 11" paper. It includes an introduction, a "thinking metric" paragraph, a conversion table, a few examples of customary American-metric equivalents, a photograph of Ohio's first metric sign, and a chart indicating the distances between eight major Ohio cities in both miles and kilometres.

h. Metric Reference Chart: This chart, on 8-1/2" x 11" paper, gives various units of length in both metric and U.S.; practical equivalents; abbrebiations; and a brief discussion of the International Metric System.

5.1.2 Current Package

The contents of the package increased as Ohio's involvement in the metric work program and the metric research project increased. The package now contains all the items described under Section 5.1.1 plus the following:

a. ODOT News Releases: This consists of copies of various news releases that were sent to the news media throughout Ohio as follows:

(1) February 14, 1973. Announced the erection of the first four metric signs, giving their locations.

(2) June 21, 1973. Announced the erection of eighteen more metric signs, giving their locations. Described Ohio's five-phase program.

(3) July 31, 1973. Announced the start of Metric Project #1 with a brief description of what was involved.

(4) November 16, 1973. Announced that the Director of Transportation had requested his Department to conduct a three-stage metrication study, in cooperation with the Ohio State University, for the federal government.

(5) November 19, 1973. Announced the date of the public hearing for Metric Project #2.

(6) April 22, 1974. Announced the fact that a third metric project on State Route 188 in Perry County had been initiated. Described project briefly.

(7) June 21, 1974. Announced that motorists were being interviewed to get their opinions on the metric signs and the metric system in general. Gave a few results from earlier surveys.

(8) July 5, 1974. Announced the pending trip of a three member metric research team to England to study that country's metrication processes and experiences.

(9) August 23, 1974. Announced the bid opening date for Metric Project No. 2 (HOC-93-0.14). Briefly described the project and its location.

(10) October 21, 1974. Announced upcoming ground breaking ceremonies (10-25-74) for Metric Project No. 2. Briefly described this project and Metric Project No. 1.

b. Photographs of Metric Project No. 1: Two photographs to visually show Metric Project No. 1 were added to the package.

(1) One photograph shows the sign which was located at the beginning of the project identifying it as "Ohio Metric Project No. 1" and stating that the Road Construction was for the next 5 miles or 8 kilometres.

(2) The second photograph shows a paving machine applying the asphalt overlay with Director Richley and District 5 Deputy Director Petty measuring the depth of the asphalt with a metric rule.

c. Additional Information: The Public Information Bureau of ODOT is planning additions to this package within six weeks to two months. Included will be photographs of Metric Projects 2 and 3, an outline of Metric Project No. 3 and plans for Metric Project No. 3.

5.2 Metric News Releases

The standing policy of the Ohio Department of Transportation has been, and will continue to be, to keep the public informed as to what ODOT is doing as the metric program develops. Periodic news releases to newspapers, magazines and television stations has been one of the principal methods used.

The first news release sent out by the department was on February 14, 1973 for the first metric signs along I-71.

A second release was sent out in mid-March of 1973 on the Director's testimony before the U.S. Subcommittee on Science, Research and Development of the U.S. Committee on Science and Astronautics of the House of Representatives. This testimony outlined Ohio's five point program.

A third release was sent in June of 1973 to locate an additional 18 signs that were to be posted along interstates in Ohio.

In July of 1973 a release was sent outlining the first metric project in Licking County where metric measurements were used for the first time in the U.S. for the entire resurfacing project. This short term project was also completed during this time.

In November of 1973 another release was sent to tell of the public hearing for the second metric construction project in Hocking County.

Also in November, there was a release sent to show that ODOT was negotiating with the FHWA for the metric study.

In April of 1974, a release announced the third metric construction project which involves Perry County. The release also notes that the ODOT had begun working on the FHWA study.

In June of 1974, a release identified the results of the Public Use and Adaptation Phase of the metric program. The results showed that the public gets more out of certain types of signs and that the signs do help in translating English to Metric measurements.

In July of 1974, a release announced the pending trip of a three-member metric research team to Great Britain to study that country's metrication processes and experiences.

A release in August of 1974 announced the bidding date for Metric Project No. 2 (HOC-93-0.14)

The last news release was in October, 1974 and announced the ground breaking ceremonies for Metric Project No. 2 and briefly described Metric Project No. 1

Additional news stories will be released by ODOT as Metric Project No. 3 is started and as the construction of Metric Projects No. 2 and No. 3 progresses.

5.3 Correspondence With the Public

Both the Bureau of Public Information and the Metric Research Team have received, and answered, numerous letters from interested individuals, companies, organizations and governmental agencies. The Bureau of Public Information has answered 198 letters and the Metric Research Team 18 letters. A description of these letters is contained in Chapter 6 - Phase 5. Public Reaction.

5.4 Speeches

The Metric Research Project Manager was a speaker at two meetings in December of 1974. These speeches were delivered at the ODOT Operation and Design Safety Seminar on December 4, 1974, and at the annual meeting of the Ohio Ready Mixed Concrete Association on December 5, 1974. A description of these speeches is given in Chapter 6.

Members of the Metric Research Team will continue to give speeches on metrication whenever possible. Tentative plans call for speaking to the Queen City Chapter of the National Association of Power Engineers in Cincinnati, Ohio and to the Franklin County Chapter of the American Society of Civil Engineers in Columbus, Ohio.

Chapter 6--Phase 5. Public Reaction

Observation and analysis of public reaction to the metric signs and other phases of metrication.

6.1 Introduction

This phase (Phase 5) of Ohio's metric work program was originally designed to analyze the public reaction to the metric signs only, but has been expanded to analyze the public reaction to various other phases of metrication. This phase differs from the motorist reaction part of Phase 3, which questioned motorists while they were in transit, in that it considers the public reaction to the signs and metrication in general. This reaction has been obtained by the following described procedures.

6.2 Correspondence With The Public

a. By the Bureau of Public Information

Out of 198 letters sent to the public, only five were in response to negative correspondence. These five letters were among the 28 letters received from adults who could not be identified by profession or association. Another one of these letters was in response to a letter which supported Ohio's metric program but protested the spelling of "meter" vs. "metre".

The categories of responses were broken down into six classifications with some subclassifications within three of the categories.

There were 55 letters addressed to professionals. Of these, 20 were to members of the news media; 11 were to highway or transportation-oriented representatives; 10 were to public service representatives (i.e. local safety councils, etc.); and 14 general representatives of business and industry.

There were eight letters to youth including two directed to college students; five to junior high; and one to the elementary level. There were 80 letters sent to professionals representing all levels of education from grade school through college.

There were four letters to political representatives and 23 to special interest groups, including four to metric organizations and four to motorist organizations.

Forty-one of the above letters were sent in response to letters after publication of the Interim Report. These letters were more favorable to Ohio's program and metrication in general than were the previous 157. This would appear to indicate that publicity concerning Ohio's program is reaching more people and affecting them in a manner as to be favorable to the metrication program.

Many requests were received for metric information which were not answered by letter. Immediately following publication of a news release, approximately 25 requests were received daily for general metric information but after a period of time the number of requests usually dropped to approximately 10 per week. Another release spurred it upward again. No record was kept of these letters since they required no special attention, except forwarding the metric pamphlet.

b. By the Metric Research Project Team

The Metric Research Team received eighteen (18) letters of inquiry from individuals, companies, organizations, and governmental agencies located in 8 different states, Washington, D.C. and 2 foreign countries (Canada and Peru). A brief summary of these letters of inquiry follows:

- College Student, Bay de Noc College, Escanaba, Michigan (January 22, 1974).

Student was doing a paper on converting to the metric system and desired information on our highway metric signing program.

·Metric Conversion Committee, Edmonton, Alberta, Canada (February 19, 1974).

Desired information in the field of metric conversion, principally in connection with highway signing. They are considering adopting a 30 metres arc definition of a degree of curve. Wanted any information on metric standards applicable to highway location, design and construction.

·International Sanitary Supply Association, Chicago, Illinois (March, 1974).

Requested a metric brochure. Wanted to know correct nomenclature for temperature in metric units.

·New Mexico Department of Highways, Santa Fe, New Mexico (April, 1974).

Desired to know ODOT's efforts in the area of metrication.

·Santa Fe Engineering Services, Orange, California (April 22, 1974).

The writer had read an article in a periodical which mentioned that ODOT was preparing some highway plans and specifications in metric measurements. He stated that his company is occasionally faced with this problem (metrics) in foreign industrial plant access and service road design. Desired information on our work in metrics.

·Queen City Chapter, National Association of Power Engineers, Cincinnati, Ohio (May 6, 1974).

Desired any information concerning the development of the metric system within the State of Ohio. Would like a representative from ODOT to speak to the Chapter on the subject.

•Metric Committee, Illinois Department of Transportation, Springfield, Illinois (July 15, 1974).

Illinois D.O.T. recently formed a Metrication Committee and wants to do some pilot projects using the metric system. Desired information and comments concerning metrication.

•The Wayne Smith Company, Inc., Washington, D.C. (July 29, 1974).

Requested 300 copies of metric reference chart from our metric package and wanted us to send 300 copies of our metric system guide to the U.S. Travel Service (Dept. of Commerce, Wash. D.C.). Also, wanted a description of the method used by ODOT to implement public information and analyze public feedback.

•Physics Department, Oregon State University, Corvallis, Oregon (August, 1974).

Professor in Physics Department requested information regarding the erection of metric highway signs in Ohio.

•Research Engineer, Virginia Highway Research Council, Charlottesville, Virgina (August, 1974).

Desired to know about ODOT's "changeover" to metrics and for us to provide him with any information we have concerning metrication. Of course, we informed him that we are not changing over to metrics but are preparing for the possibility by a study of the problems and by pilot projects.

•American National Metric Council, Washington, D. C. (September, 1974).

ANMC desired photographs of the metric display at the Ohio State Fair for possible inclusion in a future issue of its publication "Metric Reporter".

·Ministry of Transportation and Communication, Lima, Peru (September, 1974).

Desired computer programs for structural design of bridges and for highway design projects. In exchange, they offered to send back to us the programs after they have been converted to the metric system.

·North Electric Company, Galion, Ohio (October, 1974).

Desired to know the cost of conversion to log mile exit numbers on the Interstate system and what the possibility was for complete highway metrication in Ohio.

·North Dakota Highway Department, Bismark, North Dakota (October 14, 1974).

The North Dakota Highway Department is contemplating the design of a road and bridge project by the metric method. Requested a set of our metric design plans for a road and a bridge.

·Associate Editor, J. J. Keller and Associates, Inc., Neenah, Wisconsin (November 6, 1974).

This firm is going to publish a "yearbook of metric progress" in January 1975 as a supplement to their "Metric System Guide". Attached to the letter was a blank questionnaire form containing five questions on metric involvement of our organization. These questions desired information on the following subjects: (1) metric activity in our department; (2) existence of a metric planning committee or metric task force; (3) pilot programs of metric utilization; (4) metric progress in our department in 1974; and (5) metric programs planned for 1975.

·Foreign Projects Division, FHWA, Washington, D. C. (November, 1974).

Requested contract plans for our pilot metric projects. He planned to use them to assist a Southeast Asian country.

·California Metric Committee, U.S. Department of Commerce, San Francisco, California (November, 1974).

The chairman of this committee requested information relative to Metric Project No. 2 (HOC-93-0.14).

·Metric Committee, Illinois Department of Transportation, Springfield, Illinois (November 27, 1974).

Illinois D.O.T. Metrication Committee is considering putting on a seminar and inviting all States in FHWA Region 5 to attend. Purpose of the seminar would be to identify current metrication activities and explore opportunities for cooperative efforts among the States. The letter solicited ODOT's comments and suggestions.

6.3 Other Contacts With The Public

Another method used to ascertain public reaction to metrication was by attending or speaking at various meetings and seminars.

a. On December 14, 1973, the Builders Exchange of Columbus (BXC) held a meeting which was attended by representatives of the BXC, the Ohio State University, the Construction Specifications Institute, Women in Construction (WIC), the City of Columbus, the Ohio Contractors Association and the Ohio Department of Transportation. The purpose of the meeting was to coordinate all efforts in the educational preparation of the construction industry to convert to the metric system. ODOT explained its program. Columbus stated that they were going to design and construct a small sewer project. WIC said they were planning a conference on metrication, similar to one put on earlier by the University of California at Los Angeles. All attendees

thought this seminar was a good idea and pledged their support. All had a positive approach to metrication and were in favor of the United States adopting the system.

b. On November 14, 1974, the American National Standards Institute (ANSI) held a seminar entitled "Standardization/Metrication is Everyone's Business" in Cincinnati, Ohio. This seminar was attended by ODOT's Metric Research Project Manager. Although he was not on the program, the Project Manger had the opportunity to talk to people from all phases of business and ascertain their interests in metrication and to tell them of ODOT's program. Interest was high in ODOT's program and all comments were favorable.

c. On December 4, 1974, The Metric Research Project Manager was a speaker at the third annual Operation and Design Safety Seminar sponsored by the Ohio Department of Transportation. In attendance were 175 engineers and technicians involved in highway design and operation. The Project Manager described ODOT's metric program in detail. While the presentation was very well received there were some negative comments, such as: Why metricate, the way we are doing it is okay; the costs will far outweigh the benefits; and education of the public and of technical people will be more difficult than portrayed.

d. On December 5, 1974, the Metric Research Project Manager was a speaker at the 37th Annual Meeting of the Ohio Ready Mixed Concrete Association. This meeting was attended by over 100 members of the association. The Project Manager briefly described ODOT's program, the metric research project and the two metric construction projects highlighting the use of concrete and possible conversion problems. As before, the speech was very well received and generated many questions, which were answered. Negative comments were: the costs will outweigh the benefits and the transition period will be difficult, especially when aggregate sizes are metricated, since ready mixed concrete suppliers will have to carry an inventory of both metric and customary aggregates to be able to fulfill orders in either metric or customary units.

6.4 News Clippings

A third method used in the attempt to ascertain public reaction to metrication was by analyzing various news stories published in newspapers and magazines. Metric articles were clipped by ODOT personnel and by a news clipping service, and a file maintained.

a. Ohio Department of Transportation's Clips. ODOT has maintained a file of news clipping, pertaining to metrication, obtained from various publications. This file now contains over 110 clippings from large newspaper dailies around the state and from a few magazines. All the magazine articles clipped on Ohio's program included a photograph showing the Ohio metric sign on I-71 on the way to Cleveland being erected.

Approximately 40% of the clips concerned Ohio's metric work program. Most of the earlier clips referred to Ohio's metric signing program and three to appearances of ODOT's Director testifying for metrication. The later clips were of Ohio's metric construction projects or of the pending trip to England by the research team and were follow-ups of ODOT's news releases. All articles were neutral or favorable to ODOT's metric program.

The remaining 60% of the clips were miscellaneous news stories not involving ODOT. Many of these clips covered a series of 3 articles by Steve Meiring, Mathematics Supervisor with the Ohio Department of Education and announcing various workshops and meetings. Generally, about 55% of these miscellaneous news stories were informative with no bias; 35% were favorable and 10% were unfavorable of switching to the metric system.

Three of ODOT's clippings are worth individual note:

(1) An October, 1974 story out of Willow Grove, Pennsylvania (a suburb of Philadelphia) described a local service station's experiment in selling gasoline by the litre; the gas was measured, pumped and priced by the litre.

The experiment was a cooperative effort with the State Bureau of Weights and Measures and was to last three months. It was designed to introduce the American public to the possible future nationwide conversion to the metric system. A service attendant reported "Eighty percent of the customers really liked it. They figure they are getting the same amount and aren't getting cheated. Those who don't like it are mostly older generation who find it kind of hard to change". Two negative reactions were "that's un-American" and "it took me 40 years to learn one system and now it will take me another 40 years to learn a new one". The service station kept one island of pumps operating in gallons just in case someone rejected the litre experiment.

(2) On December 22, 1974 the largest newspaper in Columbus, Ohio, the Columbus Dispatch ran a full page article on metrication. The information for the article was taken from a recent publication by the Ohio Department of Education, Division of Educational Redesign and Renewal. This article contained paragraphs on "A Metric World", "What is the Metric System", "Think Metric", and "Learn Metric". Additionally, it gave a "Table of Metric-English Equivalents" and a table showing desirable weights (masses) for men and women ages 25 and over. Also included were a map of Ohio showing distances between principal cities in kilometres and a metre measuring scale (actually drawn to true scale) with instructions on how it could be used to make a metre stick.

(3) A January 2, 1974 article out of Washington, D. C. gave a brief discussion about the history of metrication and mentioned the experiment in (1) above and the fact that four states have erected metric highway signs. Of particular interest in this article is the fact that the nation's third largest soft drink company is replacing its standard 16 ounce and 32 ounce (one quart) bottle sizes with half-litre and one litre bottles. The new bottles will be short and squat both to dramatize the changeover and to permit stacking greater numbers in the same space. The company said that it is converting in line with the "universal trend to metric".

b. News Clipping Service. As follow-up of the Department's news releases a clipping service was hired late in June of 1974 to collect published information about metrics from various newspapers in Ohio. This service was used for a one month period and started immediately following the June 1974 news release explained in Section "a", above, and was in effect when the July 1974 news release was made. Seventy-six (76) clips were received from this clipping service. Thirty-four (34) of these clips were general metric stories, thirty-one (31) concerned ODOT's release of the metric survey of motorists and eleven (11) of the trip to England by members of the Metric Research Study Team.

General Metric Stories

Of the 34 clips received in this category, 17 were clips of the series of 3 articles by Steve Meiring, Mathematics Supervisor with the Ohio Department of Education. The clips were from newspapers throughout Ohio and included newspapers in the following cities: Loudonville; Miamisburg; Perrysburg; Bluffton; Sylvania; Waverly (2 newspapers); Rossford and Ottawa (both published clips of two of the series' articles); and Hamilton and Bowling Green (both published clips of all three articles). This story traced the history of the metric system and metrication progress in the United States; explained the metric system and gave a short table of length, area, weight or mass and volume conversion factors; and briefly discussed the advantages and disadvantages of the metric system.

Ten of the clippings announced upcoming metric workshops or meetings. Of these, six announced a metric workshop to be held at five different universities (Capital, Malone College, Ohio, Bowling Green State and Miami) during the Summer of 1974. These workshops were sponsored by the Ohio Department of Education and were primarily designed to instruct teachers on how to get the metric message across in the classroom. Each workshop was of five days duration. Two clippings announced a metric workshop to be held at the Lancaster branch of Ohio University. The workshop was held in four sessions of 3 hours each in the evening and was

designed to teach the use of the International System of Units (SI). One article noted that the Clark Technical College's Department of Continuing Education was offering a five-week course on "Understanding the Metric System". The course was to be taught in five - 2 hour sessions over the five weeks. The tenth clipping concerned a four-day meeting of the Interstate Consortium on Metric Education being held in San Mateo, California. The meeting was set up to provide guidelines in metrics for text publishers and teachers.

The remaining seven clippings in this category were miscellaneous in nature. Five of these clips were of articles written by staff members of newpapers in Cleveland, Willoughby, Middletown, Painesville and Findlay. These articles were mainly in a humorist vain giving conversion factors for common items and dealing with cooking, sports, clothing and terminology. These articles were basically either in favor of the changeover or neutral except for the one on cooking which was slightly negative. One clip was of an article from the Los Angeles Times reprinted in a Mansfield newspaper and concerned itself primarily with teaching of metrics to elementary aged school children in Ottawa, Canada. The last clip was from a Cincinnati newspaper which reported that a local junior high school's math classes had conducted a survey regarding student opinion of the metric system. Individual questionnaires were distributed by members of the class to all seventh and eighth graders. Results indicated a general dislike of the metric system and a strong preference for the use of the English system of measurement. Math students, who handled the survey from the beginning to end, found the project both interesting and educational.

<u>Stories Concerning ODOT's Metric Survey of Motorists</u>

The June 21, 1974 ODOT news release included the following information about ODOT's metric survey of motorists:

- A total of 3,440 motorists had been interviewed in two surveys (2000 in the first and 1440 in the second) with one more survey planned.

- 75% of the motorists showed that they were learning the relationship of miles to kilometres.
- Precise signs showing the exact relationships, such as one mile equals 1.61 kilometres, are more effective in helping the motorist understand conversion.
- Intensive signing does not seem to aid in conversion since too many facts are presented on one sign. When two or three destinations are listed on the same sign with the distances in miles and kilometres, motorists found them hard to read in the short time available at highway speeds.
- Answers to a question asking if the motorist favored change to the metric system were: Those in favor, 47% in the first survey and 44% in the second; undecided, 14% in the first and 20% in the second; and against, 39% in the first and 36% in the second survey.

Thirty-one clips were of stories relating to the above news release concerning the survey of motorist reaction to the metric signs. Twenty-nine of these stories were direct reprints of the ODOT news release (either a full text version or a short summary) without editorial comments. They were printed in newspapers published in the following Ohio cities: Dresden, Versailles, Leipsig, Leesburg, Waverly (2 newspapers), Struthers, Minster, Greenville, Cardington, Greenfield, Wilmington, Harrison, Hamilton, Fairborn, Newcomerstown, Niles, Canton, Ashland, Circleville, Warren, Columbus, Dayton, Marion, St. Marys, Fostoria, Piqua, and Mansfield (two articles published on different dates in same newspaper). The purpose of listing all of these different cities is to show that the coverage of news releases concerning ODOT's metric activities was state-wide and the size of cities ranged from very small to large.

One article (published in Steubenville) printed a summarized version of the news release but added an opening and closing paragraph by the editor. The opening paragraph stated "Apparently some day we are going to change from our present system of measurements to the metric system in use now in most European countries and Canada. Its going to be confusing but the Ohio Department of Transportation is doing

a good job of advance planning". The closing paragraph said "Apparently the public will have little choice in deciding the change and its probably a good thing. Most of us undoubtedly would want to leave well enough alone. Many of us have trouble enough with present signs".

The last clipping (published in Elyria) was of an article written around the ODOT news release. The newspaper ran its own survey of 50 people living in the Elyria area. The results of this survey conflicted with the ODOT findings. For example, only 18% understood the difference between a mile and a kilometre; 96% were aware of the impending changeover with 88% opposed to such a move; and most felt the change would be confusing, especially for older persons. The article would have to be considered negative in nature to a metric changeover.

Trip to England Stories

Eleven clips were of stories relating to the pending trip to England by three members of ODOT's Metric Research Study Team. Ten of the stories were merely reprints of all or portions of ODOT's news release. One article published in Toledo editorialized on the news release, praising the metric efforts by ODOT and closing with the following comment "Although Congress has dragged its feet, inching timidly toward enactment of a national metrication act, others are moving independently to learn and work with the new system. International trade in both directions had dictated the U.S. transition. Ohio has a good leg up on the task".

6.5 Metric Surveys at the Ohio State Fair.

Public opinion polls were conducted at the 1973 and 1974 Ohio State Fairs. The questionnaires used are shown in Figures 22, 23 and 24. Questionnaire-A in the 1974 poll repeats all pertinent questions from the 1973 poll for the purpose of comparison but has the over 36 age group broken into 36-50 years old and 51 and over. Questionnaire-B, given only at the 1974 fair, is a redesign Questionnaire to probe into the respondee's actual awareness and knowledge of the metric system. For the purpose of analysis, the questions are grouped into three basic categories, those related to familiarity with the metric system, those related to dual distance signs, and those related to opinion of the metric system and public information. Chi-square tests (discussed in TASK 2 Section 4) were used to analyze the data. Primary emphasis was placed on comparison of responses by different age groups for each question and on the change in response by age group from 1973 to 1974. For this the 36-50 and 51 and older groups in 1974 were combined to compare with the over 36 group in 1973.

6.5.1 Public Familiarity with the Metric System.

Question A-3 and B-2 deal primarily with the public's general familiarity with the metric system. The responses to these questions are compiled in Table 38. There was a significant difference in the responses given by different age groups in all three polls. In each case the professed knowledge of the metric system decreased with each succeeding age group older than the 19-25 group. In none of these age groups was there any significant difference in responses from the 1973-A poll to the 1974-A poll. There was a significant increase in the number of respondees 18 and under professing familiarity from 1973 to 1974 in question A-3. However, the responses to question B-2 for the 18 and under group are not more positive than those for the 19-25 group as was the case in Question A-3 for 1974. From this information it can be concluded that for those 19 and older the percentage familiar with the metric system will decrease as age increases and that no improvement was noticed from

STATE OF OHIO

DEPARTMENT OF TRANSPORTATION

OPINION POLL - A (1973)

NAME (OPTIONAL): ______________________________

ADDRESS (OPTIONAL): ______________________________

PLEASE ANSWER EACH QUESTION BY PLACING AN 'X' IN THE APPROPRIATE BOX.

1.	ARE YOU A RESIDENT OF OHIO ?	1 ☐	YES
		2 ☐	NO
2.	WHAT IS YOUR AGE ?	3 ☐	18 AND UNDER
		4 ☐	19 - 25
		5 ☐	26 - 35
		6 ☐	36 AND OVER
3.	ARE YOU FAMILIAR WITH THE METRIC SYSTEM ?	7 ☐	YES
		8 ☐	NO
4.	WERE YOU AWARE THAT 92 PERCENT OF THE WORLD'S POPULATION NOW USES THE METRIC SYSTEM ?	9 ☐	YES
		10 ☐	NO
5.	DID YOU KNOW THAT THE U.S. CONGRESS IS CONSIDERING NATIONAL ADOPTION OF THE METRIC SYSTEM BY 1983 ?	11 ☐	YES
		12 ☐	NO
6.	HAVE YOU SEEN OHIO'S NEW METRIC DISTANCE SIGNS (LIKE THE ONE ON DISPLAY) POSTED ALONG THE INTERSTATE HIGHWAYS ?	13 ☐	YES
		14 ☐	NO
7.	DO THE SIGNS HELP YOU UNDERSTAND THE RELATIONSHIP BETWEEN MILES AND KILOMETERS ?	15 ☐	YES
		16 ☐	NO
8.	DO YOU GENERALLY APPROVE OF THE NEW METRIC SIGNS ?	17 ☐	YES
		18 ☐	NO
9.	SHOULD OHIO INSTALL MORE METRIC SIGNS ?	19 ☐	YES
		20 ☐	NO
10.	DO YOU FAVOR THE U.S. ADOPTION OF THE METRIC SYSTEM ?	21 ☐	YES
		22 ☐	NO
11.	SHOULD OHIO DO MORE TO EDUCATE THE PUBLIC ABOUT THE METRIC SYSTEM ?	23 ☐	YES
		24 ☐	NO
12.	WHERE WAS THIS FORM FILLED OUT ?	25 ☐	STATE FAIR
		26 ☐	COUNTY FAIR
		27 ☐	OTHER

13. COMMENTS ______________________________

____

____

____

Figure 22. Questionnaire Used at 1973 Ohio State Fair.

STATE OF OHIO

DEPARTMENT OF TRANSPORTATION

OPINION POLL - A (1974)

OHIO IS PRESENTLY CONDUCTING A RESEARCH PROJECT FOR THE FEDERAL GOVERNMENT CONCERNING THE ADOPTION OF THE METRIC SYSTEM OF MEASUREMENT. THIS QUESTIONNAIRE IS AN IMPORTANT PART OF THIS RESEARCH. YOUR HELP IN ANSWERING THE FOLLOWING QUESTIONS WILL CONTRIBUTE TO THE OVERALL SUCCESS OF THE PROJECT.

CITY ____________________

COUNTY ____________________

PLEASE ANSWER EACH QUESTION BY PLACING AN "X" IN THE APPROPRIATE BOX.

1. ARE YOU A RESIDENT OF OHIO?
   - 1 ☐ YES
   - 2 ☐ NO

2. WHAT IS YOUR AGE?
   - 3 ☐ 18 AND UNDER
   - 4 ☐ 19 - 25
   - 5 ☐ 26 - 35
   - 6 ☐ 36 - 50
   - 7 ☐ 51 AND OVER

3. ARE YOU FAMILIAR WITH THE METRIC SYSTEM?
   - 8 ☐ YES
   - 9 ☐ NO

4. WERE YOU AWARE THAT 92 PERCENT OF THE WORLDS POPULATION NOW USES THE METRIC SYSTEM?
   - 10 ☐ YES
   - 11 ☐ NO

5. DID YOU KNOW THAT THE U.S. CONGRESS IS CONSIDERING NATIONAL ADOPTION OF THE METRIC SYSTEM BY 1983?
   - 12 ☐ YES
   - 13 ☐ NO

6. HAVE YOU SEEN OHIO'S NEW METRIC DISTANCE SIGNS (LIKE THE ONE ON DISPLAY) POSTED ALONG THE INTERSTATE HIGHWAYS?
   - 14 ☐ YES
   - 15 ☐ NO

7. DO THE SIGNS HELP YOU UNDERSTAND THE RELATIONSHIP BETWEEN MILES AND KILOMETERS?
   - 16 ☐ YES
   - 17 ☐ NO

8. DO YOU GENERALLY APPROVE OF THE NEW METRIC SIGNS?
   - 18 ☐ YES
   - 19 ☐ NO

9. SHOULD OHIO INSTALL MORE METRIC SIGNS?
   - 20 ☐ YES
   - 21 ☐ NO

10. DO YOU FAVOR THE U.S. ADOPTION OF THE METRIC SYSTEM?
    - 22 ☐ YES
    - 23 ☐ NO

11. SHOULD OHIO DO MORE TO EDUCATE THE PUBLIC ABOUT THE METRIC SYSTEM?
    - 24 ☐ YES
    - 25 ☐ NO

Figure 23. Questionnaire "A" Used at the 1974 Ohio State Fair.

STATE OF OHIO
DEPARTMENT OF TRANSPORTATION

OPINION POLL - B

OHIO IS PRESENTLY CONDUCTING A RESEARCH PROJECT FOR THE FEDERAL GOVERNMENT CONCERNING THE METRIC SYSTEM OF MEASUREMENT. THIS QUESTIONNAIRE IS AN IMPORTANT PART OF THIS RESEARCH. YOUR HELP IN ANSWERING THE FOLLOWING QUESTIONS WILL CONTRIBUTE TO THE OVERALL SUCCESS OF THE PROJECT.

CITY ______________________ COUNTY ______________________

PLEASE ANSWER EACH QUESTION BY
PLACING AN "X" IN THE APPROPRIATE BOX.

Question	No.	Answer
1. WHAT IS YOUR AGE?	1	☐ 18 AND UNDER
	2	☐ 19 - 25
	3	☐ 26 - 35
	4	☐ 36 - 50
	5	☐ 51 AND OVER
2. HOW WELL ACQUAINTED DO YOU BELIEVE YOU ARE WITH THE METRIC SYSTEM OF MEASUREMENT?	6	☐ NOT AT ALL
	7	☐ LIMITED KNOWLEDGE
	8	☐ MODERATE KNOWLEDGE
	9	☐ VERY KNOWLEDGEABLE
3. WHICH IS THE GREATER DISTANCE, A MILE OR A KILOMETER?	10	☐ MILE
	11	☐ KILOMETER
	12	☐ NOT SURE
4. WHAT IS LARGER, A CENTIMETER OR AN INCH?	13	☐ CENTIMETER
	14	☐ INCH
	15	☐ NOT SURE
5. HOW MANY COUNTRIES IN THE WORLD DO YOU BELIEVE USE THE METRIC SYSTEM OF MEASUREMENT?	16	☐ LESS THAN HALF
	17	☐ HALF
	18	☐ MORE THAN HALF
	19	☐ MOST
6. WHICH IS LONGER, A YARD OR A METER?	20	☐ YARD
	21	☐ METER
	22	☐ NOT SURE
7. HAVE YOU SEEN OHIO'S NEW METRIC ROAD SIGNS (LIKE THE ONE ON DISPLAY)?	23	☐ YES
	24	☐ NO
8. WHERE WOULD YOU LIKE TO SEE FUTURE ADDITIONAL METRIC ROAD SIGNS PLACED? (YOU MAY CHECK MORE THAN ONE)	25	☐ ON INTERSTATES
	26	☐ ON STATE HIGHWAYS
	27	☐ ON COUNTY ROADS
	28	☐ ON LOCAL ROADS
	29	☐ OTHER (SPECIFY) ________
9. THE METRIC ROAD SIGNS HELP MOTORISTS UNDERSTAND THE RELATIONSHIP BETWEEN MILES AND KILOMETERS.	30	☐ STRONGLY DISAGREE
	31	☐ DISAGREE
	32	☐ NO OPINION
	33	☐ AGREE
	34	☐ STRONGLY AGREE
10. WERE YOU AWARE THAT THERE IS A PROPOSAL IN THE U.S. CONGRESS TO CHANGE THE U.S. TO THE METRIC SYSTEM OF MEASUREMENT?	35	☐ YES
	36	☐ NO

11. IF YOUR ANSWER TO QUESTION 10 IS NO, DO NOT ANSWER THE NEXT TWO QUESTIONS. IF YOUR ANSWER TO QUESTION 10 IS YES, PLEASE COMPLETE THE QUESTIONNAIRE.

Question	No.	Answer
12. HOW DID YOU FIRST LEARN ABOUT THE PROPOSED CHANGE?	37	☐ RADIO
	38	☐ T.V.
	39	☐ NEWSPAPERS
	40	☐ MAGAZINES
	41	☐ OTHER (SPECIFY) ________
13. HAS PUBLICITY ABOUT OHIO'S METRIC ROAD SIGNS MADE YOU AWARE THAT THE CHANGE TO THE METRIC SYSTEM IS TAKING PLACE?	42	☐ YES
	43	☐ NO

Figure 24. Questionnaire "B" Used at the 1974 Ohio State Fair.

Table 38. General Familiarity With Metric System.

Question		Reply	≤ 18		19-25		26-35		36-50		≥ 51		Total	
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A-3	1973	Yes	518	65	539	71	340	67	353	51			1750	63
		No	275		219		171		341				1006	
	1974	Yes	529	75	567	71	364	66	309	59	144	47	1913	66
		No	180		227		191		217		163		980	
B-2		Not At All	91	12	79	10	104	18	78	19	76	30	428	16
		Limited Know.	333	43	307	41	230	41	199	48	89	36	1158	42
		Moderate Know.	284	37	268	36	153	27	103	25	61	25	869	32
		Very Know.	62	8	95	13	78	14	31	8	22	9	288	10

from 1973 to 1974 in these groups.

Questions A-4 and B-5 deal with the public's awareness of world use of the metric system. The responses to these questions are compiled in Table 39. For age groups 19-25 and older there was no significant difference between the responses to Question A-4 in 1973 and 1974. In neither year was there a significant difference in responses between the age groups. The only significant change was a large increase in awareness from 1973 to 1974 in the group 18 and under. For question B-5 there was a significant difference between age group responses. However, the only noticeable differences are that a larger percentage of those 51 and over answered "less than half" than other groups, and a smaller percentage of this same group answered "Most" than other groups. The only thing conclusive about this information is that there was no improvement in positive responses between 1973 and 1974 for those over 18 years of age.

Questions A-5 and B-10 deal with the public's awareness of proposed legislation to convert the United States to the metric system. The responses to these questions are compiled in Table 40. In each of the three polls the 18 and under group was significantly less aware of the legislative proposals than the other groups. For all practical purposes there was no difference among the groups 19-25 and older. In no age group, however, was there any significant change in responses to question A-5 from 1973 to 1974. Although the responses to question B-10 were signifIcanly more positive than those for A-5, this is probably due to the way it was worded. Question B-10 is more general in nature, not specifying an exact year. The conclusions from the above analyses are those under 18 are less aware of proposed metrication and that there has been no improvement from 1973 to 1974.

Questions B-3, B-4, and B-6 deal with the public's familiarity with three metric units of linear measurement, the kilometre, the centimetre, and the metre. The responses to these questions are compiled in Table 41. For question B-3 there was a significant difference among the responses

Table 39. Awareness of World Use.

Q.	R.	≤ 18		19-25		26-35		36-50		≥ 51		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1973	Yes	507	64	587	79	382	74	513	74			1989	72
	No	288		177		134		188				787	
A-4													
1974	Yes	516	73	592	75	416	75	382	73	224	71	2130	73
	No	193		202		141		145		90		771	
B-5	1/2	79	10	52	7	33	6	33	8	35	15	232	8
	1/2	50	7	47	6	34	6	28	7	15	6	174	6
	1/2	268	35	292	39	207	37	140	34	99	41	1006	37
	Most	369	48	361	48	287	51	210	51	92	38	1315	49

Table 40. Awareness of Proposed Legislation.

Q.	R.	≤18		19-25		26-35		36-50		≥ 51		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1973	Yes	622	78	679	89	463	89	625	89			2389	86
	No	180		86		55		74				395	
A-5													
1974	Yes	563	80	708	89	502	90	484	92	277	89	2534	87
	No	145		88		53		43		35		364	
B-10	Yes	666	88	695	94	531	94	384	93	224	93	2500	91
	No	95		48		36		29		18		226	

Table 41. Familiarity With Units.

Question	Reply	≤ 18		19-25		26-35		36-50		≥ 51		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
B-3	Mile	432	56	480	64	339	60	264	64	139	57	1654	60
	Kilometer	257	34	223	30	168	30	110	27	72	29	830	30
	Not Sure	79	10	44	6	58	10	36	9	35	14	252	10
B-4	Centimetre	136	18	121	16	87	16	60	15	46	19	450	16
	Inch	590	78	578	78	408	72	286	70	144	61	2006	73
	Not Sure	35	4	46	6	69	12	61	15	48	20	259	11
B-6	Yard	121	16	112	15	90	16	88	22	55	23	466	17
	Metre	584	76	564	76	387	69	251	62	133	56	1919	70
	Not Sure	60	8	65	9	87	15	67	16	48	21	327	13

of different age groups, but no definite pattern. For B-4 and B-6 there was also a significant difference among the responses of different age groups, but in these cases a definite continuous drop-off of correct responses occurs for those 26 and older. However, the more important factor for highway people is the comparison of correct answers to the three questions. In the first three age groups there was a significantly smaller number who answered B-3 (the mile-kilometre question) "correctly" than did B-4 and B-6.

From the first three groups of questions in this category one important observation can be made. This is that public information programs have in general increased neither public awareness nor familiarity with the metric system from 1973 to 1974, except in the age group 18 and under. However, there is a good possibility that their increase in familiarity was obtained at school (see Section 6.5.3) and not through public information programs. The fact that fewer younger people knew the relationship between the mile and the kilometre than those for centimetre and inch and metre and yard should also be a cause for concern.

6.5.2 <u>Dual Distance Signs</u>.

Questions A-6 and B-7 asked whether or not the respondee had observed Ohio's dual distance signs. The responses to these questions are compiled in Table 42. As should be expected, there was no difference in responses to A-6 and B-7 in 1974, except the inexplicable difference for the group 51 and over. As also should be expected significantly more people in each age group had seen the signs in 1974 than had in 1973.

Questions A-7 and B-9 deal with the public's opinion of the usefullness of the dual distance signs in helping the public understand the relationship between miles and kilometres. The responses to these questions are compiled in Table 43. There was a large significant difference between the responses of the group 18 and under for A-7 from those of the other groups in the 1973 poll. A much smaller percentage of this group believed the signs helpful.

Table 42. Public Observance of Dual Distance Signs.

Q.	R.	≤18		19-25		26-35		36-50		≥51		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A-6 1973	Yes	610	76	634	84	453	88	615	88			2312	83
	No	188		125		64		86				463	
A-6 1974	Yes	578	82	726	92	514	92	503	95	291	94	2612	90
	No	130		66		42		27		20		285	
B-7	Yes	638	83	684	92	517	91	380	92	205	84	2424	88
	No	132		62		49		32		40		315	

Table 43. Public Opinion of Usefulness of Dual Distance Signs.

Q.	R.	≤18		19-25		26-35		36-50		≥ 51		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A-7 1973	Yes	439	57	520	70	356	71	452	67			1767	66
	No	334		228		144		220				926	
A-7 1974	Yes	423	61	521	67	366	67	354	67	201	66	1865	65
	No	271		260		182		171		105		989	
B-9	Str.Dis.	45	6	41	6	43	8	28	7	34	14	191	7
	Dis.	73	10	84	11	67	12	39	10	25	10	288	10
	No Opin.	178	23	85	11	63	11	46	11	26	11	398	14
	Agr.	374	49	396	53	287	51	238	58	129	53	1424	52
	Str.Agr.	93	12	137	18	104	18	53	14	28	12	420	17

However, an insignificant increase in positive responses from 1973 to 1974 for this group coupled with insignificant decreases in the other groups made the difference between age groups insignificant in 1974. While the results of analysis on question B-9 indicated a significant difference in the responses of different age groups, no real pattern existed. The only observations worth noting are that the 51 and older group had the largest percentage strongly disagreeing, the 19-35 had the largest percentage strongly agreeing, and the 18 and under group had the most no opinion.

Questions A-8, A-9, and B-8 deal primarily with the public's general approval of the dual distance signs. The responses to these questions are compiled in Table 44. The results of the compilation and analysis of questions A-8 and A-9 show that responses to the two questions are nearly identical in each year. There is no doubt that the answer to question A-8 biased that for A-9, since A-8 immediately preceeded A-9 and asked for essentially the same information. Thus the following discussion pertains to both questions. In both years there was a significant difference in responses among the different age groups, with the most positive responses in the 19-25 age group and these generally decreased as age increased. While the percentage of positive responses decreased from 1973 to 1974 in each age group this was only significant for the 19-25 and 36 and over age groups. There was no significant differences among age groups for the responses to question B-8. However, it should be of note that only a few respondees suggested that no more dual distance signs be placed on highways or a remark of similar nature.

To determine if the observance of Ohio's dual distance signs actually did help the public understand the relationship between miles and kilometres the data were broken into two groups. The groups were those who had seen the signs (Yes to B-7) and those who had not (No to B-7). The responses to question B-3 (mile-kilometre question) were then compiled by age for each of the two groups and compared. This compilation is shown in Table 45. In each age group a larger percentage of those who had seen the signs answered

Table 44. Public Approval of Dual Distance Signs.

Question	Reply	≤ 18		19-25		26-35		36-50		≥ 51		Total	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A-8 1973	Yes	532	68	610	81	369	73	467	69			1978	73
	No	255		143		134		207				739	
A-8 1974	Yes	469	67	586	74	378	69	326	62	180	58	1939	67
	No	232		206		167		201		129		935	
A-9 1973	Yes	527	67	611	81	381	76	480	72			1999	74
	No	254		144		121		188				707	
A-9 1974	Yes	463	66	585	74	398	73	330	63	192	62	1968	69
	No	236		203		148		192		118		897	
B-8	Interstate	474		535		379		230		129		1745	
	State Highways	410		439		313		206		107		1475	
	County Roads	188		213		151		92		47		691	
	Local Roads	225		232		161		101		38		757	
	None	37		33		36		30		17		151	
	Misc.	13		14		7		5		3		42	

Table 45. Effect of Dual Distance Signs on Knowledge of Relationship Between Miles and Kilometres.

Age	B-7, Have Observed Signs?											
	Yes						No					
	B-3 Which is larger Mi. or km						B-3 Which is larger Mi. or km					
	Mi.		km		Not Sure		Mi.		km		Not Sure	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
≤ 18	378	57	228	34	60	9	74	53	43	31	22	16
19-25	455	65	206	29	38	6	32	51	21	33	10	16
26-35	319	61	154	29	50	10	25	51	15	31	9	18
36-50	256	67	97	25	30	8	11	34	15	47	6	19
≥ 51	124	61	59	29	19	10	12	31	12	31	15	38
Total	1532	62	744	30	197	8	154	48	106	33	62	19

B-3 correctly than those who had not. This difference was significant in the 19-25, 36-50, and 51 and over age groups. For the two oldest age groups the percentage answering B-3 correctly was cut in half from those who had seen the signs to those who had not. Thus it can be concluded that at least for those over 36 the use of some selected dual distance signs help in understanding the mile-kilometre relationship. They may in fact help for other groups too, but in no way to the same extent.

6.5.3 Public Opinion of the Metric System and Public Information.

Those questions relating to public information and the general opinion of the public are A-10, A-11, B-12, and B-13. The responses to these questions are compiled in Table 46.

Question A-10 asked whether the respondee favored the United State's adoption of the metric system. In both the 1973 and 1974 polls there was a significant difference among the responses given by different age groups. The most favorable responses in each year coming from the 19-25 group with the percentage of those favoring adoption decreasing as age increased and also for those 18 and under. This clearly follows the pattern of responses to question A-3 (see section 6.5.1). The relationship between familiarity and favorability to change will be discussed later in the section. However, where familiarity remained the same from 1973 to 1974, except for those 18 and under, favorable responses toward metrication decreased in every age group. This decrease was significant in the 19-25 and 36 and older groups.

Question A-11 asked whether Ohio should do more to educate the public about the metric system. In both the 1973 and 1974 there was a significant difference among the responses of different age groups. The basic trend is the same as that for the previous question and question A-3. The effect of familiarity on desire for more education will be discussed later in this section. There was no trend

Table 46. Public Opinion of Metric System And Public Information.

Question	Reply	≤ 18 No.	≤ 18 %	19-25 No.	19-25 %	26-35 No.	26-35 %	36-50 No.	36-50 %	≥ 51 No.	≥ 51 %	Total No.	Total %
A-10 1973	Yes	489	63	569	75	341	68	450	67			1849	68
	No	290		189		162		223				864	
A-10 1974	Yes	424	60	544	69	350	64	279	54	156	51	1753	61
	No	278		248		200		241		151		1118	
A-11 1973	Yes	667	84	715	94	454	90	602	88			2438	87
	No	127		47		52		79				305	
A-11 1974	Yes	620	88	721	91	498	90	427	81	248	80	2514	87
	No	87		70		55		97		63		372	
B-12	Radio	59	10	98	15	54	11	43	12	29	14	283	12
	T.V.	130	22	158	24	119	24	62	17	47	23	516	22
	Newspapers	96	16	188	29	207	41	166	46	94	47	751	33
	Magazines	28	5	73	11	51	10	43	12	9	4	204	9
	Family/Friends	30	5	40	6	30	6	10	3	3	1	113	5
	School	238	40	70	11	21	4	4	1	2	1	338	15
	Work	1	0	4	1	3	1	9	3	10	5	27	1
	Misc.	9	2	21	3	20	4	22	6	7	3	79	3
B-13	Yes	543	82	540	80	423	81	313	84	187	87	2006	82
	No	119		135		98		61		27		440	

whatsoever in the change from one year to the next. Positive responses increased significantly for the 18 and under group, decreased insignificantly for the 19-25 group, remained the same for the 26-35 group, and decreased significantly for the 36 and over group.

Question B-12 asked where the respondee had first learned of the proposed conversion of the United States to the metric system. The data speaks for itself and no statistical analysis is necessary. Except for those 18 and under, the way information reached the public was through the mass media.

Question B-13 asked whether publicity about Ohio's metric signs had made the respondee more aware that metrication is taking place. Positive responses ranged from 80% to 87% but the difference between age groups was not significant.

To determine whether the respondee's familiarity with the metric system affected his or her opinion on the United States metricating (A-10) and the State of Ohio educating (A-11) the data were divided into two groups. These were "yes" responses to A-3 (Are you familiar with the metric system?) and "no" responses to A-3. For each of the above groups the responses to question A-10 (Do you favor the United States adoption of the metric system?) were compiled by age group. This is shown in Table 47. For every age group there was a large significant drop in "yes" answers to A-10 by the group unfamiliar. Therefore, it can be concluded that professed familiarity has a strong effect on the respondee's acceptance of metrication. Responses to question A-11 (Should Ohio do more to educate the public about the metric system?) were compiled in the same manner as above. This is shown in Table 48. For every age group there was a small significant decrease in positive responses to A-11 from those who were familiar to those who were not. However, familiarity is probably not that much a factor on the desire for Ohio to do more "educating". In compiling the information it was observed that nearly every "no" answer to A-11 appeared where the

Table 47. Effect of Familiarity on Opinion For Conversion.

Age	A-3, Yes - Familiar				A-3, No - Not Familiar			
	A-10, Yes		A-10, No		A-10, Yes		A-10, No	
	No.	%	No.	%	No.	%	No.	%
≤18	371	65	204	35	53	42	74	58
19-25	461	77	139	23	83	43	109	57
26-35	289	73	106	27	61	39	94	61
36-50	220	65	121	35	59	33	120	67
≥ 51	104	58	76	42	52	41	75	59
Total	1445	69	646	31	308	39	472	61

Table 48. Effect of Familiarity on Desire For Further Education.

Age	A-3, Yes Familiar				A-3, No Not Familiar			
	A-11, Yes		A-11, No		A-11, Yes		A-11, No	
	No.	%	No.	%	No.	%	No.	%
≤18	513	89	64	11	107	82	23	18
19-25	556	92	46	8	165	87	24	13
26-35	360	92	33	8	138	86	22	14
36-50	286	84	55	16	141	77	42	23
≥ 51	154	83	31	17	94	75	32	25
Total	1869	89	229	11	645	82	143	18

respondee had also answered "no" to A-10. The most likely conclusion then would be that the respondees who were in favor of metrication nearly all wanted Ohio to do more to educate the public. Those who were not in favor of metrication were split in their feeling on this matter.

Chapter 7. Evaluation of Task 2

Basically, Task 2 was well worth the effort and money expended to summarize and evaluate the Ohio Department of Transportation's Five Phase Metric Work Program. It proved a valuable partner to Task 1, Literature Review and Analysis, by filling gaps in the literature.

Evaluation of Task 2 as it affected the operation of a State Highway Agency will be fully covered in Task 3, Identification of Problem Areas. In this chapter it will suffice to state some general impressions.

(1) Design of metric highway plans is easy, given the proper instructions and tools to work with. ODOT's Design Phase would have been accomplished much easier if a metrication chief had been appointed at the beginning of the Program with the authority to make binding decisions.

(2) Construction of metric projects can be accomplished with relatively little problem if the requirements placed on the contractor are realistic in terms of availability of metric supplies and material; and if the Contractor provides his employees with proper metric tools where required.

(3) Education of personnel should pose no problems to either the Highway Agency or the Contractor if it is kept in mind to only educate to the degree needed, when needed.

(4) Traffic signs showing dual unit messages can be helpful in educating the public in the relationships between linear measurements of the two systems.

(5) A public information program is worthwhile to inform the public of metrication activities. However, activity by Highway Agencies should be limited to their field of endeavor and the general education of the public in the metric system left to agencies better equipped to perform this function.

(6) Public acceptance of the metric system is greater when they are more aware of the metric system and its relationship to the customary American system. This proves the value of a public education program.

TASK 3

Identification of Problem Areas

Chapter 1. Introduction

The objectives of TASK 3 are to:

a. Identify problems in conversion to and use of the metric system in highway planning, location, design, construction, quality control, maintenance, inventory and traffic control.

b. Enumerate alternative solutions to these problems and analyze the feasibility of implementing such solutions.

In the following chapters primary emphasis will be placed on what will be required for highway metrication, highlighting specific problem areas and evaluating alternative solutions to these problems; and where information is available, costs will be discussed.

The information has been presented in such a manner that it can be easily used by administrators at various agency levels. Chapters 2 and 3 discuss requirements at the national level and at the state and agency level respectively, those being policy and organizational decisions. Chapters 4 through 7 discuss the requirements within the four major areas of a highway agency; Location and Design, Right-of-Way, Construction, and Operations, respectively. The impact of metrication on subdivisions within each major area will be discussed with emphasis on three categories; software (manuals, records, policies, etc.), hardware (equipment and materials), and personnel. Conclusions reached concerning the impact of metrication on the highway mode of transportation are listed in Chapter 8 and Recommendations of steps to be taken are discussed in Chapter 9.

Chapter 2. National Aspects of Metrication

Metrication will be a country-wide process which can be managed in several ways, ranging from a centrally decided, planned and executed approach to "evolutionary" metrication with an indifferent government, incremental changes and slow speed of progress -- quite like the United States in the past few years.

2.1 National Organization

Before highway metrication can take place the nation as a whole must decide to go metric, as no single industry or agency has anywhere near the impact necessary to cause the coordination of various governmental and private agencies required for an organized metrication process. This can only take place through control of a Federal agency, such as the British Metrication Board in Great Britain. Such an agency's power could range from dictating the metrication process to acting as a coordinator of voluntary metrication activities. The British government used the latter, performing the following: a) coordination by soliciting timetables from industries and integrating them into one national timetable, b) Provision of incentives through its purchasing power, c) organizing changes (like highway signing) which must occur on a national level at the same time, d) advice and arbitration on matters concerning the measurement system and rules of use. This method parallels quite closely the suggestions by most major U.S. industries that metrication follow three major rules; the rule of "reason", "voluntary" change, and "no subsidies". The rule of reason dictates that change should occur if and when it is most advantageous. Voluntary change means simply no law should be imposed requiring metrication of a product. The use of subsidies as an incentive should be avoided as they tend to produce less efficient methods of metrication. However, the British indicated they had a great deal of trouble in coordinating because they had no legal power to control metrication activities. Recommendations concerning the path to take in national metrication will be discussed in TASK 4, Program for Research.

2.2 National Decisions Affecting Highway Metrication.

Most of the information obtained indicated that the selection of units and the changing of national standards and specifications for various products have the first priority of all metrication activities. These must be determined for the country as a whole. The highway field must take part in these decisions or may find itself working with impractical units and standards. Sections 2.2.1 and 2.2.2 discuss units and standards in more detail with emphasis on the effect on highway metrication.

2.2.1 Units.

Most countries that have recently converted to the metric system have chosen the SI system of units previously discussed in Tasks I and II. The basic advantage of the system is its coherence, each derived unit being obtained directly from base units without any constants. However, with regard to the highway field several rules (especially the recommended use of only prefixes expressing 10^{3x} multiples of base units) provide very unwieldy units. Therefore, acceptance of more practical metric units should be considered. Several examples are listed below. Use of the cubic millimetre (mm^3) and the cubic metre (m^3) as the only measurements of volume leaves an excessively large gap especially in the measurement of liquids. The use of the litre is recommended as an intermediate unit. The use of the square metre (m^2) and square kilometre (km^2) for area measurement causes the same problem in measuring real estate. The hectare (10^4 m^2) appears to be the most suitable unit for this purpose. The SI unit of angular measure is the radian which is really impossible to work with in the area of highways; however, the SI system does allow use of the degree where the radian is impractical. The British felt the changeover to a 400^o circle with 100 minutes and 100 seconds as subdivisions would not be worth the effort and expense, even though it might be easier to work with. Therefore the use of the degree as we know it (360^o in a circle) does not appear undesirable. The use of the kilometre per hour as the measure of vehicle speed is

recommended in lieu of metre per second. Use of the tonne (1000 kg) may also be helpful as a unit of mass. Although many educators recommend the use of the centimetre and decimetre because they can be visualized more easily than the millimetre, their use does not appear necessary in the highway field. There is strong sentiment in Britain and continental Europe to use the kilogram-force in lieu of the newton, however newton is recommended as it makes a clear distinction between force and mass which is an integral part of the metric system.

2.2.2 Product Standards

Once units are chosen the task of revising national standards and specifications must begin. This is probably the most important phase of metrication and may well be the most difficult. The information obtained from Great Britain indicated that this process took much longer than expected. The British Standards Institute covers all specifications writing in Great Britain, yet many specifications required 6 or 7 drafts before final approval. The fact that the United States has several standards writing organizations such as ASTM and SAE, compounds the problem even more. Since many specifications and standards used by highway agencies refer to these "base" specifications it is imperative that this work get an early organized start with representatives from the highway field taking an active part. The necessity of coordinating this Task to avoid the "chicken and egg" argument is imperative. Without it the designer would say "we will have to wait to see what sizes industry provides us before we metricate," while industry in turn would counter with "we will not change until you tell us what you want." Although neither is a good reason they do make excellent rationalized excuses for those against metrication.

There are three basic methods of converting product specifications and standards from imperial to metric:

a) Simple arithmetic conversion of the dimensions from Imperial to metric ("soft" conversion).

b) Arithmetic conversion followed by rationalization to a nominal metric value ("hard" conversion).
c) Complete change of standard sizes to reduce product lines ("metric rethinking").

The main advantage of the first is that it requires no change except the use of a different unit of measurement. The major disadvantages are that the nominal Imperial dimensions do not convert evenly to metric, leaving odd numbers with which to work, and that the products still do not agree with commonly used international metric sizes.

The main advantages of the second are that it gives reasonable numbers to work with and in many cases allows the substitution of a standard American size during transition. This substitution can be handled in two ways. The first is by relaxing size tolerances to include the old standard size. As an example, the American Concrete Pipe Association has distributed a set of proposed SI standard sizes for circular pipe shown in Table 49. Note how the sizes have remained relatively the same with the permissible variation in diameter including the present standard size plus maximum tolerance. However, relaxing of tolerances would have a negative effect on material quality and never really require a nominal metric size. The more logical approach would be to handle this in material callout; calling for either the metric standard size or the American standard size where metric would not yet be available. For example a plan could call for a "hard" metric size pipe of 600 mm with its pertinent specification or allow as an alternate an old standard 24" pipe (610 mm). This of course could only be done for a specified time period in which all manufacturers should have completed their changeover. The major disadvantages are that it would require the agreement of a large number of people and that it would require changes in manufacturing equipment while still not producing products agreeing with commonly used metric sizes.

The major advantage of the third alternate is that it can produce a line of products that could be smaller in number, reducing inventory costs, or could be more in tune

Table 49. Proposed Concrete Pipe Sizes

PROPOSED SI (METRIC) STANDARD			PRESENT U. S.	
Designated Diameter of Pipe mm	Permissible Variation Internal Dia. of Pipe		Internal Diameter of Pipe	
	Minimum, mm	Maximum, mm	Inches	Millimetres
100	100	110	4	101.6
150	150	160	6	152.4
200	200	210	8	203.2
250	250	260	10	254.0
300	300	310	12	304.8
375	375	390	15	381.0
450	450	465	18	457.2
525	525	545	21	533.4
600	600	620	24	609.6
675	675	695	27	685.8
750	750	775	30	762.0
825	825	850	33	838.2
900	900	925	36	914.4
1050	1050	1080	42	1066.8
1200	1200	1230	48	1219.2
1350	1350	1385	54	1371.6
1500	1500	1540	60	1524.0
1650	1650	1695	66	1676.4
1800	1800	1850	72	1828.8
1950	1950	2000	78	1981.2
2100	2100	2155	84	2133.6
2250	2250	2310	90	2286.0
2400	2400	2465	96	2438.4
2550	2550	2620	102	2590.8
2700	2700	2770	108	2743.2
2850	2850	2925	114	2895.6
3000	3000	3080	120	3048.0
3150	3150	3235	126	3200.4
3300	3300	3390	132	3352.8
3450	3450	3540	138	3505.2
3600	3600	3695	144	3657.6

with internationaly used metric sizes. The Industrial Fasteners Institute has proposed an optimum system of metric fasteners which it estimates can save the industry one fourth of the annual turnover by reducing inventories. The major disadvantages, however, are that it requires agreement of a large number of people and changes in manufacturing equipment. Transition would also be made quite difficult if sizes of products were radically changed from those previously used. Also the decision would have to be made on whether to design the new lines to fit an optimum system or to meet commonly used international sizes.

Various products will naturally require different courses of action in the revision of specifications and standards, depending on such factors as the national and international market for the products, production changes required for "hard" conversion and/or "metric rethinking", and interdependency with specifications and standards for other materials. The wishes of the United States highway industry, including various public and private agencies, will have the greatest impact on the revision of specifications and standards for those products for which it is one of the larger consumers. The major problem (involving highways) that the British encountered was with specifications for aggregates and sieve sizes, and this particular area will require a great deal of attention (See TASK 1, Section 3.5).

Ideally, all material standards and specifications should be ready before other phases of metrication start. Since revision of standards takes years, as discovered in Great Britain, this would be impossible. To circumvent this problem in Great Britain basic and key standards were revised first. For other specifications metric addenda were issued with suggested metric values to be used in the interim period, before completely revised specifications were issued. Regular standards publications were not dual dimensioned per se but were issued with blanks next to all imperial figures. The addenda then were used to fill these blanks.

While the time required to change specifications and standards to metric was underestimated by the British, the cost of change to meet these specifications was grossly overestimated. Although accurate cost data was not available the maximum cost reported was 2% of the annual turnover for a small firm. Most major firms indicated that by taking advantage of the attrition cycle along with realistically converted specifications the costs ran well under 1% and in many cases less than 0.1%. One supplier indicated that "the decision not to finance any costly research" on the cost of metrication was the company's first substantial savings.

2.3 National Highway Policy and Standards.

The task of rewriting national highway policy and standards will have to take place in conjunction with the revision of national product specifications and standards, as these are guidelines for the policy and standards of nearly every highway agency within the country. The revisions will have to be coordinated with those product standards previously discussed in section 2.1.2; however, since these will be the primary tasks of national highway agencies they merit additional discussion.

In Great Britain nearly all national highway policy is covered by the Department of the Environment, while in the United States both the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) are involved quite deeply with national highway policy. The cooperation of these two agencies at the top level is imperative for this phase to go smoothly.

In general the three methods of metrication discussed in section 2.1.2 also hold for metrication of highway policy and standards, however, there is strong evidence to suggest that the second alternative is the "best" for most dimensions used in standard highway policies. Since the end product of highway standards obviously remains in this country and continual research is conducted into revising these standards

"metric rethinking" appears to be unwarranted. Because most of the "end product" will be built by people in the field, "soft" conversion with its "odd" units would appear unwieldy. "Hard" conversion not only gives field people "nice" numbers to work with, but also does not require excessive changes in road building equipment already on hand (see Section 6.2 of this task). Great Britain used this method on one of their major areas of conversion, carriageway widths, and from reports received road builders had little trouble with the new dimensions. The design of Metric Project No. 2 (HOC-93-0.14) in Ohio's five phase program employed the same method for typical section dimensions. The contractor who was awarded the project felt that there would be little trouble in working with these dimensions.

However, dimensions are not the only phase requiring revision. For example, recommended scales to be used on highway plans must be determined. The SI system suggests scales in the 1, 2, or 5 times 10^x series, however, it was found in design of the two projects in Ohio's Five Phase Program that the inclusion of other scales may be useful such as the 1:400 used on Metric Project No. 3 (PER-188-03.84) for horizontal plan and profile scale. Determination of the standard definition of degree of curve will be required with concurrent changes in superelevation and spiral standards. The 100 metre definition is the one commonly used by countries employing the metric system. Whether the revision of driver and object height, the basis for site distance criteria, will be necessary and what they should be will have to be determined. Speed limits in metric units will have to be determined along with revision of traffic control policy such as the Manual of Uniform Traffic Control Devices. This would be an excellent opportunity to speed up standardization of national traffic control policy through federal coordination of states' traffic control metrication. This is one case in highway policies and standards where "metric rethinking" may be beneficial. Since traffic control laws are state laws, coordination of this task especially sign changes (See Section 7.1) may require the threat of impounding highway funds such as for the 55 mile per hour speed limits, but only as a last resort

One of the major tasks will be reexamining the degree of accuracy of measurements in highway design and construction. Most common today are the tenth and hundreth of a foot (the latter being approximately 1/8" used in bridge design). The metric system provides no suitable replacement units, the millimetre being approximately one third of 0.01 ft., the centimetre being three times 0.01 ft. and one third of 0.1 ft., while the decimetre is three times 0.1 ft. In most cases dimensions given in highway plans to a certain accuracy (e.g. hundreths of a foot) imply a tolerance in construction of half the unit either way. In some instances tolerances quite possibly could be relaxed to allow dimensioning, and the subsequent implied tolerance, to the next larger even metric unit. However, there are tolerances that should not be relaxed, but dimensioning these in the next smaller even metric unit would imply a stricter tolerance which would cause undue hardship. The only cure for this is understanding between construction and inspection personnel that the old accuracy (e.g. 3 mm and not 1 mm where 0.01' was used) still holds in spite of the dimension. This method is that generally accepted in Britain's highway industry and does not appear to be causing problems. With regard to labeling plan dimensions, as long as only the metre and millimetre are used there is no need for dimensioning. The use of a decimal point can be used to distinguish the two, dimensions in metres containing the decimal point and dimensions in millimetres not.

2.4 Conclusion

This chapter has shown the necessary metrication processes which must first begin before metrication of a highway agency can take place. Although some specific problem areas germane to highways were cited and solutions offered, the main point made should be one of organization. Highway officials must realize that they can neither be leaders nor followers in the total effort but must take an active part in overall national metrication. They must be aware of metrication progress and do their utmost to see that necessary legislation is passed with regard to changes in highway policy.

Chapter 3. State and Agency Organization

As there must be coordination at the national government level, there must also be coordination at the state government level, and the highway agency level. This chapter consists of two sections. Section 3.1 discusses state organization in relation to the highway agency, and Section 3.2 discusses metrication organization within the agency itself. Although this chapter deals primarily with state government and state highway agencies, much of the material discussed is also pertinent to local government agencies and references at times will be made to this fact.

3.1 State Government Organization.

There are numerous interactions between various state agencies, most notable for the highway agency being those with environmental agencies and law enforcement agencies. Although coordination of the metrication of interacting agencies is a must, the major reason for organization at the state government level is the legal necessity of it. Direction must come from the top, and once the metrication process begins a vast amount of state statutes that are affected by the metrication process must be revised and timed with the process.

Statutes most affected by highway metrication are those dealing with traffic regulations. Speed limit laws must be revised to coincide with signing changes as well as laws dealing with load limits and clearances. The same holds true for local ordanances dealing with traffic laws, subdivision street widths, etc. Laws dealing with fuel taxes, the primary source of income for the highway agency, are of some concern. Presently in cents per gallon these do not convert evenly to cents per litre. If they are rounded down, revenues will be cut; and if the are rounded up there could be a public outcry. However leaving these at an odd figure is no more acceptable. Since revenues have decreased recently because of decreased fuel consumption, there has been much discussion on raising fuel taxes to compensate for this loss. The revision of the

of the statute to a rounded up metric figure could be used as a tool to help offset this loss.

Coordination of various state agencies' public information programs will also be necessary to avoid unnecessary duplication of effort. However, the public does have to be ready for the changes that will affect them, and this will be one of the major tasks of the states. To quote Ms. Helen G. Caird, President of the Society for Technical Communication at the UCLA Conference: "...a broad-based educational program should be planned to indoctrinate and convince the general public of the advantages of converting to the metric measures and also of the economic and social impacts of not converting..." The importance of this was borne out in the results from phases three and five of the Ohio Five Phase program. It was found that the public's acceptance of the metric system increased substantially with their understanding of the system. It was also noted at the UCLA Conference and exhibit that Australia's metrication, where the public was well informed, went much more smoothly than Great Britain's where the public has not as yet been exposed to a great degree. The main reason for this as given to us by the British was fear of public outcry blaming metrication as yet another factor in the tremendous inflation presently occurring in that country, as has been done with the decimalization of British currency. In other countries such as New Zealand, Rhodesia, and South Africa the public has been informed and in general have given their support.

It was found that most of the respondees (over 18 years old) to Ohio's questionnaires obtained information concerning metrication from the media (see TASK 2), most notably newspapers and television. It was also noted that after each news release by the Ohio Department of Transportation requests for information increased substantially showing increased interest, but after awhile tapered down until the next release. Thought should be given by government agencies to take better advantage of media use in educating the public. For the group 18 years of age and under school was by far the major contributor. The highway agency must be

ready to also take advantage of the educational system to educate the public where highway metrication will affect them. Cooperation of educational organizations should not be a problem, since quoting Mr. Wilson Riles, Superintendant of Public Information of the State of California: "Educational organizations are almost unanimous in their support of metrication, both nationally and within California. Here is just a very partial listing of organization support: The California Teachers Association, the California Inter-Science Council, the California Mathematics Council, the National Education Association, the National Association of Secondary School Principals, the National Council of Teachers of Mathematics, the Council for Exceptional Children, the Association of American Colleges, the Association of Classroom Teachers, the National Science Teachers Association for Educational Communications and Technology, the National Congress of Parents and Teachers."

In many instances children do teach parents. One of the best tools found to educate people in the use of the metric system and show them its ease of application is the use of comparative example problems to be worked in both systems. This method was used by both the ODOT District 10 training officer at local fairs, and the ODOT District 10 Testing Engineer on his own people. In most cases the reactions of those doing the problems were quite favorable after they discovered the problem was much simpler to work in the metric system.

Further discussion of how the highway agency can help educate the public will occur in the next section of this chapter.

An early start of state organization is a must. Once national legislation is passed states should immediately begin to pass appropriate measures to coordinate their agencies' efforts; and efforts prior to national legislation are not undesirable. Two states have already begun coordination of the metrication process. Georgia has already formed a tentative plan and Virginia's legislature recently passed Joint Resolution 28 directing all agencies to report

the effects of metrication on their operations which may be coordinated into a state plan.

3.2 State Highway Agency Metric Organization.

This section contains five parts; development of a metrication task force, timetables and guidance, training programs, public information, and total costs.

3.2.1 Development of a Metrication Task Force.

Of first priority is the need of a metrication chief for the agency, given the power to coordinate all metrication activities within the agency with each other and with those outside the agency. There was universal agreement on this point from all the information gathered for the study. The need of this coordination was quite evident in the design phase of ODOT's Five Phase Program (Task 2 Section 2.3.3) , as most of the major complaints dealt more with lack of coordination of the process than with the metric system itself. The Design Engineer on the first project designed in the metric system, HOC-93-0.14, had asked for a "steering committee" but this idea was rejected. Most information obtained suggested that the metrication chief's exclusive duty should be metrication. Depending on the size of the agency he may also have a staff to assist him. The basic requirements of the manager are as follows: that he should be bi-lingual in Imperial and metric units; have a good working relationship with people; be thoroughly familiar with agency policy, practice and organizations; and have a future in the organization.

After the appointment of a metrication chief, each unit within the agency (and their subunits on down to the lowest decision making unit) should have a person designated as a "metric officer", who will report directly to the next highest ranking office up the line. Personal requirements are basically the same, but necessary knowledge will be at the unit level. The duties of these individuals do not have to be restricted to metrication, the percentage of time spent on metric activities will have to be determined by each unit's needs

3.2.2 Timetables and Guidance

Timetables are most important. They must be realistic as to time required for conversion and must also be tied in with national timetables for products and standards. Therefore it is necessary that they be flexible and constantly updated. Each unit and subunit within the agency must present a realistic plan for metrication activities. These in turn will be compiled into an agency plan that is tied into the national metrication plan. Most estimates obtained for total length of time required for metrication of the agency were from 5 to 10 years. Times for conversion of units within the agency will vary but some estimates are included in following chapters. Formulation of these timetables must be the job of top level "metric officers".

Guidance by the higher levels should primarily be limited to scheduling the metrication activities of lower levels to fit within the timetable, providing necessary information of metrication activities outside the agency, and providing rules for metrication. Direction of actual work to be done by each unit and subunit should, however, be left to local management. There are some instances, however, where direction of the work must come from the top. Three specific instances where this will probably be necessary will now be discussed. Since nearly all units within the agency have numerous computer programs which must be revised, work by each unit involving these programs must be directed from the top, or the data processing units of the agency simply could not handle a possible overload generated by too many revisions occurring at one time. The AASHTO Ad Hoc Task Force report listed this task as second only to signing in cost, 25% of total. However, other estimates, although listing it as a major task, felt cost would be nowhere near that amount. The work required, most of which will have to be done by data processing units is summarized below:

Redesign Input forms
Key punch instructions changed
Programs Rewritten
Saved Data changed
Saved Files Redesigned

Instruction Manuals Rewritten

Increased Data guidance as required.

Although not physically difficult work, that involving revision of specifications must also be controlled at the top level because of the extreme dependency on national specifications and standards and the fact that each unit within the agency must contribute. The biggest problem here is publication of specification during the interim. Several alternatives were proposed by ODOT personnel during interviews (Task 2 Sec. 2.3.3) such as dual dimensions, separate specs, and use of supplements. However, the "best" procedure is probably that used by the British and discussed in Chapter 2, that being leaving spaces for metric quantities in the publication and then providing supplements upon change of the particular specifications to fill in these blanks until complete revision was accomplished then publishing the final revised metric specifications. Because of the immense cost and physical effort required to change road signs and the effect on the public this task also should be the concern of top level management even though it really only affects one area within the agency.

3.2.3 Training Programs

In the AASHTO Ad Hoc Task Force report it was estimated that loss of efficiency would involve approximately fifteen (15) percent of the total cost of metrication. Three major problems noted by the British in this respect were; inability to visualize metric entities, especially forces; reduced ability to estimate "at a glance" in metric units; and older personnel having psychological difficulties in adjusting. These cannot be corrected by even the most elaborate and costly training programs, but must be overcome by working in the metric system without any Imperial "crutches". This was the major roadblock in training, "unlearning" the imperial system and avoiding comparisons so that one could think in metric. This then should be one major goal of any training program, to teach the system itself and not compare it back to Imperial.

The one basic guideline for training programs that was suggested by the British and nearly all American concerns in the process of metrication can be summarized in the following sentence. Teach them only that part of the metric system they need to know to do their job and only when they need to know it (in general this is just prior to application). In essence overtraining of an individual and poorly timed training are wastes of time and money. The British found this theory worked quite well for personnel from engineers down to laborers. This is not to say employees should not be made aware of the impending change, just that no formal effort should be made to train them until necessary.

Supervision of the training program can be handled by the agency's metrication chief. The primary concern of this individual should be to obtain and or prepare metric references to be used in training. The most important thing about the references is they be up to date, reflecting the system of units finally chosen for use in the agency. These references should then be fitted to the group who will be using them (e.g. references containing information suitable for engineers would completely confuse a laborer).

In most reported instances little actual formal instruction was given personnel. Reasons differ for various classifications of individuals. Engineers in general require the most knowledge of the new system, however, given adequate references they are quite capable of educating themselves in the system of units. Technicians whose jobs are more task oriented require less information, and given adequate exposure to the units they are required to use can become familiar with them quickly when working with them. Laborers need know only a few units, some maybe none at all. In most instances what classroom training is required can be handled by immediate supervisors who should be the most familiar with the needs of their own people. The concensus of opinion in both Tasks I and II was that on the job training (or workshops) was the most suitable way of learning to apply the units. In general, ODOT employees who worked on the design of the two projects and were given little formal

instruction had very little trouble in applying the metric system to their work after a short "adjustment" period on the job. Beyond exposure to the units needed, any further lecture type sessions would be wasted. Individual needs and experiences with training of individuals will be discussed in later chapters.

If the above guidelines are followed in educating employees costs should be held to a minimum, hopefully under the ten percent of the total cost of metrication estimated in the AASHTO Task Force Report.

3.2.4 Public Information

Although Phase Four of Ohio's Five Phase program included the distribution of general information about the metric system, the primary concern of highway agencies should be to educate the public in those metric units that highway metrication will require them to be familiar with (primarily the metre and kilometre which will appear on metric road signs, and the hectare in Right-of-Way negotiations).

One method employed by ODOT and many other states to acquaint the motorists with the kilometre is the erection of dual-unit distance signs. The results of the analysis of data from the Ohio State Fair questionnaires proved this to be a good educational tool. For those who had seen the signs the percentage answering the mile-kilometre question correctly was significantly larger than that for the group who had not, this being nearly double for those 36 years of age and older. However, saturation of a length of highway with dual-unit distance signs does not appear to improve upon the results obtained by placing only a few signs with the relationship of the two units clearly shown (e.g. City A 100 km 62 mi. or City B 161 km 100 mi.). Rather than saturating areas with dual-unit distance signs, these should be placed at selected locations throughout a state on not only interstate but also state highways, as there are many individuals who do not use the interstate system extensively.

A large number of the respondees to the questionnaires indicated this to be true.

One way the highway agency can expose the public to the hectare is that used by the negotiators on the Ohio Perry County project. That is during negotiations involving metric projects, the negotiators should make an effort to discuss the metric units with the property owner even if he still has to convert back to discuss the actual price offered.

The highway agency should have general metric information to be distributed on request. However, active participation in media presentation, educational programs, and distribution of literature of this nature should be coordinated in agencies more suited to this task, such as Education. This is not to say that the highway agency should stop all its public information on the metric system other than the road signs, but to attempt to limit it as much as possible to topics germane to highway metrication.

3.2.5 Costs of Metrication of the Highway Agency

Information on costs for metrication of highway agencies from countries presently involved in the process is almost nil. There are two basic reasons. With current world inflation it is next to impossible to separate increased costs of metrication from the natural increase in costs. In most countries metrication was an accepted fact and the procedures were done in the most efficient manner possible with little time wasted in attempting to locate where every penny went. In general the feeling was that costs were nowhere near as outrageous as some had originally predicted.

In reply to letters sent to state agencies requesting their progress in metrication only three states sent cost estimates. These are summarized in Table 50.

The most valuable thing about these large scale cost estimates is that the vast discrepancies show the utter futility of attempting them, as they are gross estimates at

best and may in fact cost more than they could possibly save. Some information was obtained on costs of a few individual items at lower levels and also some methods which could be employed to reduce these costs. These will be discussed in later chapters.

Table 50. Summary of Estimated Costs to Metricate

California*

Total Cost for Division of Highways	$10,000,000
Training	10%
Revision of (All) Manuals	10%
Standards Revision	1%
Computer Programming	25%
Highway Signs	30%
Right-of-Way Conversion	9%
Efficiency Loss	15%
Others	1%

*Input to AASHTO Ad Hoc Task Force Report.

Virginia

Bridge Design.	$ 20,000
Location and Roadway Design.	109,000
Materials Testing.	85,000
Right of Way Acquisition	50,000
Traffic and Safety	18,000,000
Equipment Maintenance and Repairs. . .	405,400
Data Processing.	215,000
Fiscal Management.	15,000
Training	130,000
Total For Division of Highways	$19,029,400

Oregon

Total Cost for converting all operations of Oregon Division of Highways $868,000

Chapter 4. Planning, Location, and Design

This chapter is divided into six sections; planning, aerial surveying, field surveying, location and design, plan preparation and drafting, and a general summary of the design phase. The first five sections are primarily concerned with hardware changes, software changes, and adaptation of personnel to these changes.

4.1 Planning

Very little information could be obtained on this phase, however, impact on planning should be relatively minor. The only area where metrication will have any impact worthy of comment is that involving traffic survey. This involves the preparation of reports and revision of stored data using kilometres in lieu of miles as a base. In general metrication of reports may be done along with manual revision and updating of the reports. Recorded data for various surveys need not be changed until it is needed. In this manner costs can be stretched out over time and the total impact reduced significantly.

4.2 Aerial Surveying

4.2.1 Software

Most of the revisions in policy will have to occur at the national level. The determination of suggested map scales and suitable contour intervals for these scales is required along with the subsequent publication of guidelines. This decision is not too difficult, as the SI scales (1, 2, 5 times 10^x) appear to be reasonable for local mapping. This is the only major software requirement for metrication of maps prepared by aerial engineering sections of highway agencies.

The major problem indicated in the metrication of surveying was the lack of a worldwide metric projection system for ground coordinates. "At this date no satisfactory replacement of the Ohio Plane Coordinate System for engineering

surveys has been devised and accepted. A world wide system based on the Universal Transverse Mercator projection with 1, 3, or 6 degree band has been suggested. There is a chance for confusion in using metric coordinates since the definition of equivalent English units has changed over the years. The (former) U.S. Coast & Geodetic Survey always based their surveys on metric measurement but the SI definition of 1" = 2.54 mm(exact) rendered all the published data obsolete. It is believed that new SI coordinates will not be available until after a new general adjustment based on world wide satellite observations is made, perhaps by 1980. Until then extensive metric surveys are likely to extend the confusion." (Lloyd Herd, ODOT Aerial Engineering Section).

Great Britain's Ordnance Survey (similar to U.S.G.S.) has actually just begun metrication. Although actual ground control has been in metric for thirty years, all published information was previously in imperial and on imperial scales. Horizontal distances have been dual dimensioned, but is estimated it will take until 1980 to revise contours. The British did not plan to revise scales as they felt it would take decades to convert all maps. This partial metrication may be the only reasonable course for an extensive interim period, especially if it is determined there is not enough benefit in changing scales and control system to offset the huge amount of work required.

4.2.2 Hardware.

Regarding equipment used in aerial engineering, metrication can be viewed as a blessing rather than a problem. Nearly all this equipment is manufactured in metric, and in the past the problem has been converting it to operate with imperial units. It should not then be a serious problem reconverting equipment back to metric by replacing a few parts such as lead screws.

4.2.3 Personnel.

The only information obtained was from interviews of ODOT's Aerial Engineering Section. Very little, if any, training was given; since many of the personnel were already familiar with the metric system. Those who worked on metric mapping for the Hocking County Project had little or no trouble working with the system, except in the case where metric contouring and cross-sectioning were attempted on the Kelsh plotters still equipped with special imperial digitizer bars. Those interviewed indicated that once these tables were changed they should have no trouble preparing contours and cross-sections for future metric jobs.

4.2.4 Problem Areas.

In general the task of metricating aerial survey in a highway agency will be relatively simple. There are no real problem areas at this level, once suggested map scales and contour intervals are determined. AASHTO estimated the cost of converting aerial and field survey to be less than 1% of the total. The one enormous problem is that with the projection system; and it lies with the Geologic Survey. The United States must decide whether they should wait for a worldwide projection system or develop their own metric ground control system before beginning the long process of map revision, or do it at all. However, this should have little impact on the highway field, as presently converted ground control points should be adequate for highway work.

4.3 Field Surveying.

4.3.1 Software.

Metric surveying manuals should be obtained but the number needed should not be great. Of more importance is providing horizontal curve, spiral and superelevation tables for centerline layout based on the metric degree of curvature. Development of these tables should be no problem, as the ones used on the HOC-93 Project were revised with the aid of the computer by ODOT's District 10 personnel.

The accuracy of measurements taken in the field will have to be determined. In general this accuracy should be coordinated with the accuracy required in construction of the project. None of these will involve any excessive costs.

4.3.2 Hardware.

As long as the system of angular measurement is not changed, theodolites and levels will not require changing. Electronic distance measuring devices are currently metric and will not be affected. This leaves only rods, chains, and tapes to be replaced. Rods can be altered by applying a metric overlay tape to the face until they have to be replaced with metric rods through normal wear. The British did this and it worked quite well. The "metric" rods obtained by ODOT crews "at double the cost of ordinary rods" appeared to be nothing more than that, a standard American staff with a metric face. Certainly applying the overlay yourself would be much cheaper. But when rods are replaced it should be with a full 4 m metric staff opposed to the fabricated "metric" rod.

Chains must be replaced, and although some are available, ODOT personnel found them to be grossly inferior to what they should have to work with. The "ideal" chain suggested would be an add chain with one decimetre added and graduated to the millimetre or at least to the centimetre. The rest of the chain would be graduated every decimetre and numbered at the metre. With this we agree, and recommend that suppliers are made aware of what is required.

Cloth tapes and metallic box tapes are available, although maybe not in quantity desired. These, however, were found to be quite suitable for the work performed with them. In general, both these and the chains cost "approximately twice as much" as standard American equipment, but their price should diminish as demand increases.

Other minor equipment that will need replacement are such things as pocket tapes, folding rules, thermometers, and spring scales. The only cost data available came from Surrey County, England (1,100 miles of road; 400,000 acres; 1,000,000 people). The replacement of survey and design equipment was 2000 English pounds (1965 money).

4.3.3 Personnel.

In general neither British crews nor ODOT crews were given any special training. They were shown the equipment, practiced with it for a short time (less than a day), and then went to work with it. Adjustment was relatively fast, ODOT crews indicating it took only a week to become confident working with the system. No more errors were noticed by ODOT personnel, and the British indicated that after a while there were fewer errors than usual. Only two problems were cited by the ODOT crews. The first was difficulty with estimating distances in metric units. However, toward the end of the projects personnel felt this had become much easier. The other was that in laying out metric centerlines one would have to recall the back "plus" because the chain was not a full station; in this case 100 metres.

The ODOT crews did indicate that each time they were taken off the metric jobs to work on a "regular" job a short adjustment period was required upon return to the metric job. Therefore, it is recommended that this procedure be avoided if at all possible during the transition period, for it hinders the crew's process in "thinking in metric".

4.3.4 Problem Areas.

There are no problem areas, with the exception of making sure suppliers are aware of the equipment required and when it is needed.

4.4 Design.

4.4.1 Software.

Discussion in this section primarily involves what metrication procedures will be required of the state highway agencies' design sections once national standards and policy are revised. Some of the input required will be very briefly discussed as it pertains to various parts of design; structure, hydraulics, and roadway. It should be the state agency's responsibility, however, to give appropriate input to these final national revisions.

(a) Structures: Before metrication can take place within the bridge unit of a state highway agency, the most important revisions that must occur at the national level are revision of AASHTO Specifications for highway bridges and development of metric standards for structual steel, reinforcing steel and fasteners. Once these are underway and input is available state agencies may begin revising formulas, design charts, standard drawings, suggested details, and computer programs. Some rough guesses as to the time required were made by Connecticut in reply to the general metric letter of inquirey and by Ohio's Bridge Bureau during the interviews. Connecticut estimated two years for revision of their computer programs and manual; Ohio estimated 2 years for revision of standard drawings and suggested details.

Design formulas were revised for the HOC-93-0.14 project and little difficulty was encountered by ODOT personnel with this task. Although some technical problems may occur, the major problem with the computer program revisions is coordination with all the other revisions that will be done by other units so that the data control unit is not swamped. Revision of most charts should be "plug and crank" procedure but not theoretically difficult in an engineering sense. Physical revision of standard drawings and suggested details will not take much time or effort. The problem is getting agreement among all the individuals with input as to the final design.

(b) Hydraulics: Although not every phase of hydraulic design is dependent on it, probably the most important revision prior to state agency metrication in this area is the development of metric standard pipe sizes. While nowhere near as important as pipe sizes, castings for inlets are of interest because AASHTO is presently conducting a study to determine if some national standards for castings could be established. With the advent of metrication this is an excellent chance to take advantage of "metric rethinking" at a very early stage. In reply to the general metric letter of inquiry sent to other states Connecticut sent a copy of a report submitted to AASHTO which contained a list of required national changes before metrication of a state hydraulics unit could take place. These are summarized below with our comments as to their importance in parentheses:

(1) Hydraulics texts, reports, and circulars (Nice to have but not a necessity),

(2) FHWA Culvert and channel flow charts (A definite necessity to avoid duplication of effort).

(3) U.S. Weather Bureau rainfall charts and records (Should be done but not required for metrication of hydraulic aspects, as it is concerned with hydrology, and in the case of frequency-duration curves these can easily be converted by the designer by changing the linear intensity scale from inches per hour to millimetre per hr. or whatever).

(4) Tide charts and tables (Should be done for benefit of coastal states but as with previous requirement should not be used as an excuse to delay hydraulic metrication).

(5) Revision of U.S. Soil Conservation Service, FHWA, and Army Corps of Engineers computer programs (Necessary to avoid duplication of effort by states using them.

The basic summary of these comments is that metrication of all hydrologic material is not a prerequisite to metrication of hydraulic material, as this input can be converted in most cases quite easily. Having metric U.S.G.S.

topographic maps would be helpful, but unfortunately they cannot be waited on.

The primary task of the state agency's hydraulics unit will be to revise standard drawings, their own computer programs, and those parts of the drainage manual not previously covered by national changes (primarily runoff formulas, design charts, and nomographs). Standard drawings pose no physical or technical problems, but require a large amount of time to obtain agreement from all individuals contributing comments. The time for revision of present standard drawings or development of new standard drawings from conception to approval now ranges from 6 months to 2 years. The revision of the computer programs probably would cause the most technical problems if the development of them was not adequately documented. A rough estimate of the time required to revise Ohio's major hydraulic design program was two man months for the hydraulic engineer. However, this does not even touch on the requirement of computer programming personnel. Runoff formulas can be converted without much difficulty and in a short period of time. These were the only metric formula actually used by ODOT personnel in the hydraulic design of the two metric pilot projects, and their revision took little time. Revision of design charts and nomographs should not be difficult once design formulas are revised since much of this task can be done by computer plotting, but again anything done by computer must be coordinated with other requirements. Height of cover tables for various sizes of culverts may also have to be revised depending on what the specifications are regarding pipe size and thickness.

(c) <u>Roadway Design</u>: The major requirement prior to metrication of roadway design at the state level is the revision of AASHTO policy manual for geometric design of highways, since this is the basis for most geometric design policy in this country. Revision of the HRB Highway Capacity Manual will also be required. If full advantage is taken of this effort, revision on the state level of geometric design policy should be a simple matter. Metric ICES ROADS computer programs used in preliminary design are

already available so no revision here is necessary (Task 2 Section 2.3.2).

State standard drawings will have to be changed, and as in the previous two cases the biggest problem will be in coordinating the ideas of everyone involved into the final revision. It took the two ODOT districts less than 2 weeks each to revise the standard drawings necessary for the Hocking County and Perry County Projects. Even though these were just redimensioned rather than drawn to metric scale it does illustrate that the process can be speeded up immensely if coordinated under the direction of one person. Once data is available concerning national policy for curves and transitions, superelevation, sight distances, and intersections and interchanges; revision of design aids such as sight distance charts and spiral and superelevation tables should be a relatively straight forward mathematical process. ODOT's Field District 10 had little trouble revising transition and superelevation tables once they developed a policy related to the metric definition of horizontal curves. Intersection and interchange details will have to be revised. Pavement design formula and charts will also have to be revised, but little additional information was gathered as to the difficulty of this and the previous task.

(d) General: To summarize the previous parts of this section, the state highway agency's task will be to revise its design manuals. If the manuals are up to date and well organized, it should not be a great problem. If the manuals are not up to date and well organized, the task will become more difficult. The District 10 Design Engineer's major complaint was locating what had to be metricated, not actually doing it. However, in the latter case metrication, even though more difficult, is actually a blessing as it requires organizing and updating manuals.

4.4.2 Hardware.

Designers require folding rules (2 metre length) and metric box tapes for field work, metric grid paper for

profile and cross-section work, and metric scales and curve templates for layout. Also some types of office calculators with built in constants may have to be revised or replaced.

Two metre folding rules are available in the United States. The ones purchased for the ODOT metric projects were "reasonably" priced. Box tapes previously discussed in Section 4.3.2 are available and of good quality. Metric grid paper was obtained for the Perry County job from a supply house in Cleveland at a "little more" than normal cost. Although designers require scales and templates, these are more related to plan preparation and will be discussed in the next section.

Very little information could be obtained with regard to total costs of replacement of these materials but it should not be excessive.

4.4.3 Personnel.

Reports from Great Britain indicated that most design personnel could retrain themselves in metric units given proper informational materials. This was also the general concensus of ODOT personnel who worked on Phase 1 of the Five Phase program, although there were some complaints relating to the provision of insufficient informational materials.

Design is one area where the initial efficiency loss could be quite great. This was especially true for ODOT's bridge and drainage designers where they attempted metric design with customary American design aids; estimates of increased work time being 25% to 100%. It is therefore imperative that design aids and materials be metricated before any metric design is attempted. Even when all necessary materials were metricated, British designers still had to do quite a bit of checking of calculation because of lack of familiarity with the units. They could not tell from experiences whether the value obtained was accurate. The average estimate of time required to obtain reasonable confidence working in metric units was about six months

4.4.4 Problem Areas.

The major problems of design metrication involve the revision of design manuals, standard drawings, and computer programs. Much effort will be required from data processing units in revision of charts, tables, graphs and computer programs. This work has to be coordinated with the normal work load of data processing units. The major problem with standard drawing revision is coordination of efforts of the contributors to the changes. One person should be given the task of making sure there is little time wasted in bickering over minor points or in procrastination in reviewing revisions.

4.5 Plan Preparation and Drafting.

4.5.1 Software.

The basic requirement is the development of a guideline for plan preparation with rules for paper size, plan scales, dimensioning, and general plan preparation. Although national guidelines may be developed for federal projects, states must decide what rules they wish to use for their own projects. A brief discussion of some of the required rules follows with recommendations as to procedure that should be followed.

(a) Paper Size: The A1 format for plans is recommended by ISO and AASHTO, and ODOT personnel found it relatively easy to work with. This should be adhered to nationwide to avoid problems with suppliers having to produce numerous different sizes thus increasing costs.

(b) Plan Scales: Although the 1, 2, 5 times 10^x series is recommended; other scales may prove useful, as it was found the jump from 2 to 5 does not give enough flexibility. The bridge detailer on the Hocking County project found the 1:40 scale worked quite well, and the 1:400 horizontal plan and profile scale used on the Perry County Project proved far superior to the 1:500 used on the Hocking County project.

(c) Stationing: There is a good reason for continued use of the "plus" with 100 metre stations, that being it saves writing on plans and layout stakes. The need of a different method of stationing to differentiate metric plans during the interim is not really valid. Metric plans can be marked with an appropriate symbol.

(d) Profile Elevations: For elevations on grade, 20 metre increments should suffice. For vertical curve elevations a 10 metre spacing could be used in most cases, but a 5 metre spacing may be desirable for sharper curves.

(e) Cross Sections: The use of 20 metre increments for cross-sections provides the benefit of very simple calculations for earthwork and seeding (Task 2 Sec. 2.3.3). However, it was noted during interviews for the Hocking County project that this may be too far for rugged terrain. In this case, 10 metre increments would be suitable and will still leave calculations much easier than they are presently under the customary American system of units.

(f) Cross Slopes: Cross slopes now given in inches per foot should be expressed in percent or metres per metre. However, those slopes now given in ratio form should remain so, since they are dimensionless and easier to work with in the field.

(g) Dimensioning and Callout: Dual dimensioning should be avoided since it clutters plans, could cause confusion, and delays adaptation to metric units. If only metres and millimetres are used there should be no need to label dimensions, if the decimal point rule discussed in Chapter 3 is applied. This should also negate the idea of all structure dimensions being given in millimetres. Productions of some prefabricated items may take many years to metricate. In the interim a mixed design is preferred over a "soft" conversion of the dimensions of these materials. Puerto Rico has done this for years and indicated they had little trouble in doing so. These could be highlighed on the plans by "boxing in" imperial dimensions.

4.5.2 Hardware.

Linens and print paper using the metric format chosen will be required. Linens had to be special ordered for the ODOT projects' roadway plans, at a high cost and with a long wait. Linens for bridge plans which require less detail were obtained by rebordering present stock. No effort was made to obtain print paper as it was cut from roll stock. All effort should be made to take advantage of revising present stock where excessive costs and long waits for metric material are involved.

Metric scales are needed, and good quality ones are presently available from larger supply houses at a cost nearly the same as customary American scales. Metric curve templates are available, but are expensive. The quote given by ODOT's District 5 personnel was $150 a set. Planimeters need only be recalibrated. Items connected with paper size such as filing cabinents and reproduction equipment may or may not have to be revised. These items should not be overlooked.

4.5.3 Personnel.

Reports from Great Britain indicate that draftsmen learned on the job to work in the metric system after being given the necessary guidelines and materials. Those who worked steadily in the metric system during transition took little time adapting, while those who changed back and forth had much difficulty. ODOT draftsmen had little trouble getting used to working in the new system without any formal training and in general preferred to learn with on the job training. The major effort in this area should be to provide personnel with proper equipment and rules of application before any attempt is made to do metric work.

4.5.4 Problem Areas.

The only real difficulty appears to be the procurement of metric size linens and paper. However, if adequate

planning to coordinate supply and demand is used this does not seem to be cause for worry.

4.6 Summary.

The major difficulty in the metrication of the location and design phase will be coordinating local revision of design policy and aids with work done on a national level, as so much of the work depends on national policy. The amount of computer work required will require coordination at the state level to avoid overworking data processing units. In general most hardware is available and costs should come down as the size of market increases. The most important task here is to see that suppliers are made aware of what is needed and when. Training appears to be almost unnecessary, however, it is vital that proper guidelines, materials and aids are provided before personnel begin work in the metric system. As discussed in Phase 2 of Ohio's 5 Phase Program, work in the metric system with proper aids is quite easy while that without proper aids and equipment is quite inefficient.

Chapter 5. Right-of-Way.

Very little information was obtained from TASK 1 regarding difficulty of Right-of-Way metrication; most information was brief and simply explained what was done. Therefore, most of the discussion will center around information obtained during interviews of personnel who worked on Ohio's Five Phase Program.

5.1 Right-of-Way Design.

5.1.1 Software.

Most of the larger cost estimates, such as the 9% of total estimated in the AASHTO report, include conversion of records. This appears to be unnecessary. Right-of-Way designers in both District 5 and 10 had no trouble taking deeds in customary American units and quickly converting these to metric in a short time. They indicated that this was very little extra work, as they presently have to

convert many dimensions in rods and chains to get feet anyway. This change takes only a few seconds on a calculator. The procedure to metricate records used by the British and also suggested by the Canadian Institute of Surveying appears to be the most reasonable to minimize cost and effort. All new records will be in metric units, and old records will be revised only when used (e.g. property transfers). Virginia's estimate of cost for Right-of-Way metrication was only $50,000 based on the above theory of records revision.

As earlier recommended, the hectare should be the accepted unit for area in real estate. However, since it is approximately two and one half times the size of an acre, the value should be expressed to three decimal places instead of two. The computer program for area calculation used by ODOT did not require revision, since an input of distance in metres would give the area in square metres in the square foot columns. It should be revised, however, to read in square metres. For the same reasons as expressed in location and design, Right-of-Way plans should not be dual dimensioned, although the British do use this method. This will probably continue until they expose the public to the metric system.

5.1.2 Hardware.

Only scales and horizontal curve templates discussed in Section 4.5.2 will be required, unless of course file cabinents and duplicators need be changed.

5.1.3 Personnel.

Since only two units were required, metre and hectare, no training was required. Designers immediately adjusted, and no loss of efficiency was noticed.

5.1.4 Problem Areas.

There appear to be none, unless efforts are made to convert past records before they are needed, which would enlarge the task enormously.

5.2 Appraisal.

5.2.1 Software.

Appraisal manuals will have to be revised, but only those connected with the "cost of replacement" method will be difficult. These require input from the building industry, but their use in general is limited to special purpose property which does not have a normal market. Metrication of the most commonly used method, "market data", will require only that cost of comparative recorded sales be calculated in dollars per hectare, front metre, square metre, etc. in lieu of dollars per acre, front foot, square foot, etc. now employed. Regarding the recorded sales used as a basis in this method, the fee appraiser who worked the Perry County project indicated that these need not be metricated ahead of time but could be revised when used. He indicated that this would not be a problem. The "income" method based on the income producing potential of a property and used primarily in support of the other two should not be substantially affected by metrication.

5.2.2 Hardware.

The only metric equipment needed by an appraiser is a metric scale to check dimensions on plans.

5.2.3 Personnel.

The fee appraisor who worked on the Perry County Project, where "market data" appraisal was done in both systems, indicated he educated himself in the metric units required and had no difficulty in doing so. He felt it would have been much easier just to do the appraisal in metric alone, as doing it in both systems was a duplication of effort. His total fee reflected this, as it was increased approximately twenty-five percent with the increase for individual parcels ranging up to one third more. He also believed that if appraisals (at least in the "market data" method) were done strictly metric a small increase might be warrented the first time only, but not thereafter. The British now do all appraisals in metric and no complaints were voiced.

5.2.4 Problem Areas.

It appears the only problem will be the revision of the manuals, which are used in the "cost" approach. These have numerous measurements and require input from the building industry.

5.3 Aquisition.

5.3.1 Software.

Metrication will require primarily decisions on how to conduct negotiations, court cases, and deed filing which next to highway signs have the greatest impact on the general public. In negotiations two methods are available: either the "give up" approach of converting everything back and negotiating only in imperial units as done by the British or preparing everything in metric and attempting to negotiate in that system with the negotiator converting only if necessary to be understood by the property owner. The first method requires additional work which in some cases may not be necessary. The second may require quick conversions, but these shouldn't be difficult as rough estimates (e.g. 10 ft. = 3 m and 2.5 acres = 1 hectare) should suffice for discussion with property owners. The latter method is preferred as it does expose the property owner to the metric system. The courts will undoubtedly be metricated, as they were in Great Britain; and if the property owner is not exposed to the metric system, he will become tremendously confused when he appears at an appropriation case, as has occurred there.

The filing of final deeds in metric should not really be a problem, if county auditors are made aware that the metric system is a legal system. Their whims, which necessitated dual dimensioning of final instruments in both ODOT projects, should not be considered as the law. Instruments should be filed in the metric system, and it should then be the problem of the county auditor to convert these if he has not yet metricated his operations.

5.3.2 Hardware.

Only metric measuring scales are needed by negotiators to scale off distances on plans.

5.3.3 Personnel.

No training was given negotiators in either District 5 or 10, and they had little trouble working with hectares and metres.

5.3.4 Problem Areas.

Getting the public to adopt the metric system so negotiations can be accomplished without need of conversion back to the old system is the only problem in this area.

5.4 Summary.

The task of metricating Right-of-Way does not appear to be overwhelming if records are revised only as needed. Metricating "cost" manuals will require outside input and some time consuming work, but in Great Britain's case the construction industry was one of the instigators of metrication and they have had little trouble in this respect. With proper public relations and coordination with the courts we should be able to avoid the one problem the British encountered because of negotiations and court cases operating in different systems.

Chapter 6. Construction

Because metrication of this phase has a large impact outside the agency, most notably that on contractors and material suppliers, a large part of this chapter is devoted to problems they will incur and what the highway agency can do to lighten the impact. The chapter contains six sections; layout, contracts and contractors, material suppliers, inspection, testing, and a summary of the construction phase. Since Phase 2 of Ohio's Five Phase Program is just now getting underway, the majority of information will be that obtained from TASK 1.

6.1 Layout.

Since basic requirements for construction layout are the same as those for field surveying in the design phase (Section 4.3), no extensive discussion is required here. One requirement which should not be overlooked is that layout personnel be made aware of the necessary accuracy of measurements for dimensions listed on plans (i.e. the fact that the dimension is given to the millimetre does not imply accuracy to the millimetre is required).

6.2 Contracts and Contractors.

6.2.1 Software.

One problem similar for both the highway agency and the contractor is that of preparing item prices for estimates and bids respectively. Because material prices were not available in metric units both the ODOT Estimating Section and the two contractors awarded the Hocking and Perry projects converted item quantities back to customary American units to prepare prices. These material price quotes will have to be listed in metric units and any calculation aids revised. This does not appear to be a difficult chore, as cost lists are constantly updated and prices for metric material will be so quoted. The greater problem might appear to be how to account for increased costs solely due to the project being metric, and might

cause construction problems. However; neither successful bidder on the two ODOT projects indicated he had substantially increased his bid prices due to any fear of construction problems. The contractor on the Perry project added $300 (of $5200) for layout, while the Hocking project contractor's bid for ready mix concrete and bituminous mix was increased to cover increased material costs for plant metrication. In Great Britain no evidence was seen of increased bids either, except for minor amounts. Therefore, unless an increased price can be factually justified agency estimators should not allow estimates to become inflated simply because the project is metric. For the first few metric projects pre-bid conferences may be quite helpful in explaining contract responsibilities under the new system of measurement.

All contract documents (plans, specifications, etc.) should be in metric for projects constructed in the metric system. Where metric standards and specifications exist for materials, a clause could be added to the contract or plan notes to allow substitution of standard American materials for metric supplies which are not readily available through no fault of the contractor. This should help decrease bid prices as it will eliminate the major worry most contractors express "What happens if we can't get metric materials?" It is far superior to granting either time extensions or price increases. However, it should only be done during a specified transition period, not indefinitely, since that would delay the metrication process. Contract documents also must be carefully written so they do not allow substitution for metric materials which would have been available had the contractor ordered early enough.

6.2.2 Hardware.

If the procedure of "hard" conversion recommended in Section 2.3 is followed, the impact of highway metrication on major equipment should be relatively minor. The British used this method and contractors had few problems adapting equipment to the new standards. Much equipment such as

pavers are adjustable within the range of dimensions any change will fall into. For other equipment, such as trenchers and power shovels, alterations on buckets proved quite easy. Replacement parts proved no problem as British firms still continued producing replacement parts even though new equipment was metric. One American supplier now in the process of metricating indicated that they planned to continue supplying standard American replacement parts for at least twenty years after metrication was completed.

Minor equipment such as hand tools for new metric equipment and rules and tapes will have to be replaced but the cost is relatively minor. Much of this is personal equipment and the problem of "who should pay" appears. The best policy is to settle the question of who pays on an employer/employee basis.

6.2.3 Personnel.

It was found in Great Britain that in general the office staff could retrain themselves. At first it took a little longer for estimators to complete the bid estimates, but this did not last long. Workers who require knowledge of the system require a day or so of on the job training but adapted quickly. These are generally craft oriented such as carpenters and masons. Some laborers don't ever require knowledge of the metric system at all. The most important guidelines are have metric plans and tools available before training, and don't train too early or you will have to retrain. There was some worry that older workmen would have difficulty because of prejudice against the system, but in general this was not the case.

What little information that has been obtained so far from the Licking County and Hocking County projects coincides quite well with this. Office staff for the Engle Construction Company (Hocking project) educated themselves and planned no excessive training program, and to date we are aware of no problems in working with the metric system.

On the Licking project (Metric Project No. 1), it took the personnel about a day to get used to working with the new system of units, but after that there appeared to be no difficulties.

6.2.4 Problem Areas.

Unless allowances are made in contracts for substitute materials where metric material may not be readily available during transition, this could become a very costly and time consuming problem. Also all effort should be made in revising standard dimensions to allow alteration rather than replacement of contractors equipment, or costs again could be excessively increased. If these two criteria are met, and plans and specifications provided in metric; there should not be any major problems for the contractor to build the project using the metric system of measurement.

6.3 Inspection.

6.3.1 Software.

Assuming that metric plans and specifications are available, the only required changes of note in this area involve documentation forms and inspection manuals. Until more inspection documentation forms are needed, most could be revised at the job site by simply crossing out customary American units and replacing them with metric units. An instruction sheet giving what has to be changed on various forms could be provided. In this way old forms need not be thrown away. When enough demand exists, new metric forms could then be printed. Inspection manuals should be revised and reprinted.

6.3.2 Hardware.

Although some materials testing such as concrete quality control and compaction is done in the field by inspection personnel, this will be discussed in the section on testing. The only other metric equipment necessary are folding rules and tapes. These are available in the United

States but care should be taken not to obtain measuring devices which have feet and inches on the reverse side. The reason for this is to prevent the worker using the imperial scale as a "crutch".

6.3.3 Personnel.

As with all other areas, engineers should be able to teach themselves. Inspectors may require some training but not much. Inspectors on the Licking County Project done by ODOT were given brief instructions of approximately one hour duration on the units they needed to know and had become reasonably well accustomed to them in one day.

6.3.4 Problem Areas.

There should not be any if personnel are given proper materials to work with and proper instructions.

6.4 Materials Suppliers.

Since the major problems involving materials suppliers, materials standards and specifications and coordination of timetables for supply and demand, were discussed in Chapter 2, this Section will concentrate more on those suppliers who will be most affected by highway metrication.

6.4.1 Software.

The major impact of "metric rethinking" (See Chapter 2) in materials production will be on the building industry and not in highway construction. Many of the materials of which the highway industry is the largest consumer or at least one of the largest are bulk materials such as sand, gravel, cement, and asphalt. In these cases the material specifications will probably change very little. Primary requirements for these items will be revision of batch designs for ready mix concrete and bituminous pavement and base materials. Although it is not extremely difficult to convert batch plants to metric (see 6.4.2), the highway agency must attempt to coordinate its demands for metric

mixes with that of other consumers in the area. One of the major complaints of British batch plant operators was continually having to change back and forth between imperial and metric. In Great Britian there was, however, one major problem with bulk materials caused by what might be termed as an oversight when specifications were revised. Sieve sizes (see 6.5) were metricated and rationalized, but the percent passing various sizes was left unchanged. Although the size differences were in general quite small, aggregate suppliers had an extremely difficult time in meeting these specifications, and thus aggregate prices have increased.

A few major non-bulk items that will be greatly affected by highway metrication are guard rail, drainage pipe and hardware, small piling, bridge railings, and light standards. For these and other items like them, the highway industry will have a large part in determining what final method of metrication will be employed for these products. It is imperative that highway agencies get an early start in preparing their ideas for metrication of these products.

Although highway metrication will not have near the same affect on items such as structural steel and reinforcing steel, the highway industry does use a large amount of these products and should be prepared to give input toward their method of metrication.

Those items listed above are only a few of the products used by the highway industry. Highway agencies must prepare lists of materials used, rating the materials by the effect highway metrication could have on them and determining what type of metrication would be most suitable to the highway industry's needs. Only then will the highway agencies be prepared to take part in the overall decision making process for these materials.

6.4.2 Hardware.

The equipment changes required for material suppliers by metrication will have a great effect on the method of

metrication and the timing of supply and demand. Some suppliers can convert equipment quite easily at a small expense. Both the ready-mix concrete and bituminous mix suppliers for ODOT's Hocking County project were willing to convert their operations to metric. The original estimated costs were $2000 and $1000, respectively, principally the cost of converting scales. Although the final cost for metricating the ready-mix plant was approximately $3500, this is still relatively minor and unit bid prices were not substantially increased. The only problem encountered was obtaining metric test weights. These finally had to be fabricated by altering customary American weights. Some suppliers may be even less affected. Aggregate suppliers may have to obtain metric sieves to check their mixes.

Other suppliers, however, have a large investment in equipment and unwise planning could cause prices to sharply increase. Concrete pipe manufacturers for example have a large investment in forms and any requirement that would cause an abrupt change would be very unwise.

6.4.3 Personnel.

Retraining of personnel should not be a great problem to suppliers, as much of the work is actually done by machines.

6.4.4 Problem Areas.

One major problem for the material supplier is the replacement of equipment. In the case of expensive equipment, replacement for metrication should to the maximum extent possible take advantage of the normal attrition cycle of equipment. Therefore, all metrication plans (specifications and timetables) must take into account equipment replacement which will be caused by the metrication method chosen.

The other major problem faced by the supplier is having a market for the metric product when he starts producing it. Most British suppliers were willing to convert if assured of a market for the product. Timing

of supply and demand must be handled at the national level, but the highway agency must provide information regarding what their metric material needs will be and when they will be needed. Lists of supply and demand must constantly be updated, so input will also be a continuous process. One problem that will arise during transition is the difficulty in distinquishing metric and customary American standard sizes where rationalized metrication has been used and sizes are quite similar. The use of a symbol indicating metric would be quite useful in correcting this problem.

To reiterate that already discussed in Chapter 2, increased costs due to materials metrication in Great Britain proved to be far less than the enormous amounts originally predicted by many who used this as an excuse against metrication. The largest cost reported was that of a small company, and it was only two percent of annual turnover.

6.5 Testing.

6.5.1 Software.

Although the vast majority of this work will be done at the national level in development of national specifications by such organizations as ASTM, the highway agency must contribute to this development. State specifications based on these national specifications must then be revised at the agency level with coordination of all departments with the agency. It should be remembered that when one specification is metricated, all subsequent specifications that it affects must be metricated accordingly. The British found this out when sieve sizes were changed, but the specifications for percent passing were not revised accordingly (See 6.4.1).

Once specifications are revised, impact of software conversion on the testing unit itself should be relatively minor. Report forms will require revisions where units are specified, but during the interim most old forms could be converted simply by crossing out the old and writing in the new unit as was recommended for construction

inspection forms. Some test procedure manuals will require rewriting. However, many test procedures (especially where precise measurements are involved) are already done in metric units.

6.5.2 Hardware.

Much precise equipment such as weights for small balance scales and graduated cylinders are already metric and will require no change. Larger testing equipment such as tensile and compression testing machines could be recalibrated. Much of the smaller equipment such as concrete control and proctor kits could be "recalibrated" without much trouble, as done by District 10 for the Hocking County project. These wear out in time anyway, and should be replaced by metric equipment. One supplier (Soiltest) in the United States indicated that they now carry many devices in metric. Minor items such as scales not already metric and micrometers should be replaced and removed to eliminate possible confusion. Molds for concrete test specimans are another item that will have to be replaced. During transition there should be some way of distinguishing metric and American equipment where these look alike.

The one problem with replacing equipment is that a definite decision must be made on what is desired, and suppliers kept informed. In Great Britain, manufacturers started manufacturing ISO sieves, but the British Standards Institute decided to use a different set of metric sieve sizes. This lack of coordination caused the price of sieves to be four times that of the old imperial sizes.

6.5.3 Personnel.

Personnel from the construction and tests division of one large British Corporation were interviewed, and they indicated they did not carry on a training program for testing personnel and had little difficulty with personnel adapting to the system. If specifications, instruction manuals, forms, and equipment all are metric most laboratory personnel should require very little training.

6.5.4 Problem Areas.

The cost of metricating a materials testing unit should be relatively minor in comparison to other costs. Estimates of costs of metrication by AASHTO and the state of Virginia were "minimal" and $85,000, respectively. The major problems will be in coordinating specifications and procedures with parent specifications and in obtaining metric equipment where replacement is necessary, and recalibrating that which can be recalibrated. The first is actually a departmental problem as indicated in Chapter 3. The second will be the task of the materials testing unit primarily, although it could be significantly lessened if updated lists of suppliers are made available by national organizations.

6.6 Summary.

The actual physical task of metricating the construction unit of a highway agency should be relatively minor. The major problem will be that of making sure metric construction contracts during transition allow substitution of customary American items where metric items may not be available, as might have originally been predicted when plans were prepared.

If care is taken in metrication of standard dimensions for highways, the contractors should have little problem adapting equipment. There should be little difficulty in building the job in metric units, if the contractor is provided with the necessary specifications from the highway agency.

Material suppliers indicated they shouldn't have any problem in metricating if they are told what is required, given time to convert to produce it, and have a market for the product when they are done. The words are simple, but the task of coordination in so doing is so enormous, that it is a national problem (see Chapter 2), which cannot be handled by one agency.

Chapter 7. Operations

Although this area requires few technical changes, it nonetheless poses the greatest physical problems during metrication.

7.1 Traffic Control.

7.1.1 Software.

This area primarily involves revision of traffic laws and manuals for traffic control devices. Speed limits are the primary concern, since it is obvious that a direct conversion is impossible. Australia replaced speed limits of 20, 35, 45, and 55 miles per hour with 40, 60, 80, 100 kilometres per hour respectively. One state in reply to the questionnaire sent out concerning speed limit sign conversion (see 7.1.2) suggested replacing 25, 30, 40, 45, 50, and 55 miles per hour with 40, 50, 60, 70, 80, and 90 kilometres per hour. Regardless of the rounded metric speed limits finally adopted, the laws will require revision to go into effect on a certain date and signs will have to be changed accordingly. The type of sign used should be distinguishable from the ones now commonly used. Most countries who have recently converted or will be converting signs to the metric system have used black numerals for the speed limit with a red circle around them. Some suggestions were made by states responding to the metric sign letter to use the abbreviation km p.h. on speed limit signs, but this is nowhere near as striking as the previous suggestion and at a glance could be confused m.p.h. which still remains on some signs.

The dimensions of sign blanks should be metricated, but the actual sizes may not have to be changed. The British metricated the physical size of their signs at almost no cost by changing the signs to some even metric dimension close to the old imperial size. Then if the metric sign blank was smaller than the old imperial, the machines could be adjusted to a smaller size. If the sign was not smaller, they would use the old imperial blank and

create a metric dimension system with enough tolerance to allow the old imperial size sign blanks. For example, for a 3' square sign blank, the new sign requirements would say, "the new metric signs shall be between 900 mm and 1 m square." Thereby allowing the old "imperial" sign blank to become "metric". Much the same would hold true for pavement marking and letter sizes on signs. Traffic signal heads are another area needing attention. The British metricated these dimensions and consideration should be given to doing so here.

7.1.2 Hardware.

The most costly task (at least in theory) for the highway agency will be replacement of highway signs. For this reason we queried the states regarding the conversion of speed limit signs to 55 miles per hour and their plans for conversion of all signs to metric. To date 33 states have replied (see Table 51). Their replies regarding cost of changing speed limit signs is the only data on actual costs for sign conversion we have been able to collect. Three estimates were given on total cost of metricating highway signs, but these vary greatly. California estimated $6,600,000 for all signs in the state, Virginia $17,300,000 for state highway signs, and Arizona $537,534 using a system of dual signs put up gradually. The data regarding actual costs are also listed in Table 3-1. It includes number of signs changed, total cost of change, cost per sign, method used, time required, percent of total speed limit signs converted, and projected cost for all speed limit signs on system. Two facts are of note in this data. The first is that the vast majority of states took advantage of overlays to reduce cost. The second is that projected cost for changing all speed signs on the system do not appear to reach any astronomical figures. It should be recalled that in most cases reported in Britain actual costs in areas other than signs (the British have not metricated the sign message) that could be attributed to metrication were much less than projected amounts.

Table 51. Results of Change to 55 MPH Speed Limit Signs Survey.

State	Number signs changed	Total cost signs	Cost per sign	Method used (a)	Time required	Percent of total	Projected costs (b)
		$1000	$		days	%	$1000
Alaska	100	1.1	11	O	14	25	4.6
Arizona	2892	44.3	15	O,N	7	85	52.1
California	2600	51.1	20	O	14	?	?
Connecticut	689	9.4	14	O	2	8	117.0
Idaho	1350	21.4	16	O,N	42	60	35.6
Illinois	4050	174.0	43	O,N	21	15	1160.0
Indiana	4000	40.0	10	O	14	70	57.1
Iowa	4779	25.0	5	O	3	85	29.4
Kansas	2972	38.6	13	O	10	60	64.3
Kentucky	3856	59.8	16	O,N	21	?	?

Table 51. (cont.). Results of Change to 55 MPH Speed Limit Signs Survey.

State	Number signs changed	Total cost signs	Cost per sign	Method used (a)	Time required	Percent of total	Projected costs (b)
		$1000	$		days	%	$1000
Maine	1800	8.0	4	O	28	40	20.0
Maryland	1650	29.3	18	O	60	20	146.3
Massachusetts	1200	40.4	34	O	(c)	50	80.8
Michigan	2858	23.9	8	O,N	21	30	79.7
Mississippi	1700	43.0	25	O,R,N	35(d)	50	86.0
Missouri	4490	32.8	7	O	3	50	65.6
Montana	1011	61.0	60	O,N	30	20	305.0
Nebraska	708	18.2	26	O,N	2	10	18.2
New Hampshire	463	4.0	11	O,N	21	10	48.9
North Carolina	5382	33.0	6	O	14	10	330.6

Table 51. (cont.) Results of Change to 55 MPH Speed Limit Signs Survey.

State	Number signs changed	Total cost signs	Cost per sign	Method used (a)	Time required	Percent of total	Projected costs (b)
		$1000	$		days	%	$1000
North Dakota	722	18.2	25	O,N	18	81	22.4
Ohio	3282	40.1	12	O	49	70	57.3
Oklahoma	5300	40.0	8	O	3	70	57.1
Oregon	687	26.0	38	O,N	14	22	118.5
Pennsylvania	1771	28.6	16	O	5	14	2040.4
South Carolina	2916	25.1		O	7	35	71.8
South Dakota	520	3.1	6	O	14	30	10.3
Texas	17204	217.8	13	O,N	9	8	2722.2
Utah	1938	33.3	17	O	42	40	83.2
Vermont	160	4.2	26	O	5	10	41.5

Table 51. (cont.) Results of Change to 55 MPH Speed Limit Signs Survey.

State	Number signs changed	Total cost signs $1000	Cost per sign $	Method used (a)	Time required days	Percent of total %	Projected costs (b) $1000
Virginia	(e)	(e)	-	O	-	-	-
Washington	1555	36.0	23	O	14	60	60.0
West Virginia	230	1.6	7	N	5	4	40.3
Wyoming	1250	22.0	18	O	15	80	27.5

Notes: (a) Methods used: "O" overlays over existing message
"N" erected new signs
"R" removed old signs

(b) Projected costs to metricate all speed limit signs on state highway system.

(c) Massachusetts submitted a total of 321 man days with no explanation of how many men or how many total days.

(d) Mississippi indicated that it took 48 hours to accomplish the change of the number required to meet legal requirements, and a total of 5 weeks to complete all the signs that were changed.

(e) Virginia submitted a cost of $17,000,000 to convert all state highway signs on their system but gave no figures for only the 55 mph signs.

Several replies from the states suggested using dual signing systems for distance and/or speed limits for a transition period ranging from 3 to 5 years. Some of the reasons given for dual message signing are summarized below.

(a) Cars made before a certain date do not have metric speedometers.
(b) It will help the motorist adapt to the new system until all signs are strictly metric.
(c) It will allow a gradual placement of metric signs and a gradual removal of customary signs later, thus stretching out the cost over a longer time period. The direct change from one system to the other would require a costly abrupt change, since separate signs cannot be in different systems along the highway.
(d) It will allow map makers and automobile manufacturers time to convert their operations related to signing.

Primary reasons for the direct abrupt change suggested by others are:

(a) Dual signs are not helpful in educating, as in general the metric message will be ignored. A good public information program would be better suited to this task.
(b) Dual signs will confuse the motorists.
(c) Dual signs raise legal questions regarding enforcement.
(d) If good planning is used the change need not be as expensive as anticipated.

One basic fallacy in the arguement for dual message signs is in premise (b). While a few dual distance signs showing the direct relationship between miles and kilometres did prove to be a useful educational tool in Ohio's Five Phase Program, extensive dual signing along the highway made no improvement and in fact slightly reduced comprehension in one instance (see TASK 2, Chapter 4). It has also been

previously shown in studies on highway signing that extensive messages on signs decrease motorists' perception of the basic intent of the message. This information supports premises (a) and (b) in the argument for a direct abrupt change.

Premise (a) in the argument for dual message signing is indeed a fact, but many of these cars will still be on on the road after the transition period. No extensive time period should be required to dual dimension automobile speedometers either. License tags are purchased every year. Small number decals, each with one of the new metric speed limits on it (e.g. four decals with the numbers 40, 60, 80, and 100), could be given out to each motorist whose vehicle does not have a metric or dual dimensioned speedometer. He would also be given a simple chart showing at what mile per hour he should place each decal. No special decals for different types of speedometers would be needed, it would take only one or two months to do this in the year of conversion, and the motorist would have a speedometer marked with the legal speed limits. Regarding premise (d) in this group, map makers and auto manufactuers do not need a transition period to convert, simply enough prior warning before any direct change is made. Up to that time, they could use dual dimensioning for the period prior to the change.

Premise (c) for direct change really should not cause difficulties. While metric signs are being added, and until customary American are removed the law could read that the customary American would be honored. When the romoval of customary American signs begins the law could be changed to read that the metric signs would be honored.

Although dual signing will spread costs over a long period of time, total costs will be increased because of sheer number of signs needed. A well planned program for a direct fast conversion will undoubtedly save in total costs, and many of the costs can be spread out over a period of years also. The best plan offered employed

overlays and is as follows: Once it is determined that signs will be metricated and what signs will look like, all worn out signs will be replaced by metric signs with an overlay showing the customary American value. The time period allotted should be long enough to replace a large percentage of signs. At the end of this time period, customary American overlays could be removed and metric overlays placed on all customary American signs remaining. These metric overlays would have been manufactured over the "waiting" time and stockpiled. Although the labor costs of making the switch will still be great, material cost will be spread out over a number of years to help reduce the impact. If this labor cost would still be too large for one year's budget the Federal government could as a last resort impound a small percentage of a states highway funds, forming a trust fund for this express purpose. The actual change would probably occur during the summer months, when advantage could be taken of summer student help.

In our opinion the choice of which method to use should be very simple. Dual signing systems probably would lead to motorist confusion and actually increase total costs which will have to be borne by the taxpayer. A well planned direct fast change coordinated with a good public information program (possibly including <u>selected</u> dual distance signs) and a good method of speedometer conversion would be cheaper in total cost and should not have any substantial negative effect on motorists. The latter is, therefore, recommended. Some recommended steps in this conversion are:

(a) Prepare an inventory of signs that have to be converted (by states).
(b) Make reasonable estimates of time required to replace certain percentages of these signs, e.g. 40, 60, 80, 100 through normal attrition (by States).
(c) Coordinate this into a national plan for date of direct change (by FHWA).

(d) Begin by replacing worn out signs with metric signs with customary American overlays (by States).

(e) In a short period, remove customary American overlays and place metric overlays on remaining customary American signs (by States).

Replacement of signal heads should pose no problem. When old ones require replacing, replace them with the metric standard. Pavement marking is no problem as this is done on a yearly basis anyway.

7.1.3 Public Information.

It is a definite requirement that the public be made aware of the impending change and be prepared for it. Use of the media is an essential part of this program during the period prior to the change. Effort should be made to distribute information with driver license renewals and auto tag sales. The highway agency should do its part in preparing the information to reflect what the changes will be. As mentioned previously a few dual distance signs placed at selected locations snowing the direct relation of the mile and the kilometre prove a useful tool in the education process.

7.1.4 Problem Areas.

This can be summarized in one word "signs". Only a well organized centrally controlled change can reduce the excessive cost predictions that have been given.

7.2 Maintenance.

7.2.1 Software.

The major impact in this area will be revision of records from a mileage log basis to a kilometre log basis

This will involve bridge records, culvert records, and pavement records. This will be a large task and in many instances will involve computer programming. Virginia estimated it would cost approximately $258,000 to redo road inventory. However, it can be done, unlike revision of signs, on an individual route basis to reduce the impact.

There is some question as to whether the actual description of the bridge, culvert, and pavement should be changed along with the revised location log. This would increase costs greatly, and actually has no real benefit. Whatever the description, the item is of customary American design and its record should reflect this. Only when the description is changed need the actual record itself be revised. If records are kept by computer and units of dimensions shown in headings rather than next to the dimension, it still should be easier to revise the program to allow inclusion of some method of signifying the dimensions are metric rather than revising all records.

7.2.2 <u>Hardware</u>.

Many states have extensive mileage log marking systems along highways. These markers undoubtedly will have to be changed with the mileage logs. It has been suggested that kilometre log markers be placed at two kilometre increments. This, however, should be nowhere near the problem of traffic sign conversion. Since the public has little use of these markers they can be replaced on a route basis over a period of time. As much effort as possible should be made to keep this coordinated with change in records. Changes in logs will also necessitate changes in odometers on inventory vehicles. Nebraska reported that they are in the process of equiping inventory vehicles with odometers which can easily be changed to read in kilometres but gave no details.

Construction equipment used by maintenance forces will have to be metricated. The problem here is the same as that of the contractor (Section 6.2) and a great deal of

further discussion would be redundant. It should suffice to say that nearly all large equipment can be adapted quite easily and need not be replaced.

As suppliers of machinery metricate there will be a need for metric tools. This should not be an extremely difficult task as metric tools are available now in the United States. The State of Maine reported they had purchased some metric diesel engines and metric tool kits. They did not indicate any great problem in obtaining the tool kits.

The major area of concern is in repair parts. Keeping dual inventories for a lengthy time period will be expensive, however, producers cannot be expected to supply old sizes indefinitely without an extreme increase in prices. For this reason every effort should be made to develop and use adapter devices and salvaged materials.

7.2.3 Personnel.

The highway worker in the field will require the same type of training required for contractors' personnel. Machinists and mechanics will have to adapt to using metric tools. The State of Maine indicated that to date they have had few problems working with or on their diesel engines.

7.2.4 Problem Areas

Many problems will involve the change from mileage-logs to kilometre-logs in records keeping. Of primary concern is the coordination of the required software and hardware changes into a realistic timetable for conversion.

The problem of repairing customary American highway items after metrication, will be one that will last for years. The basic decision each time repairs are required will be whether to completely replace and salvage parts or to repair with salvaged parts or metric parts and adapters.

7.3 Safety.

The only information obtained germane to this area other than discussion about signing was included in a report prepared by the state of Virginia. The excerpts are as follows:

"Conversion of portable and permanent scales for truck weighing operations would cost approximately $219,000.", and

"The conversion of other miscellaneous items such as accident studies, speed studies, railroad inventory and safety improvement data is estimated to cost $83,000."

Chapter 8. Conclusions.

The major conclusions derived from TASK 3 are summarized below.

8.1 National Level.

(1) Coordination of metrication activities at a national and state level is essential, and without legal power coordination is quite difficult.

(2) In selection of a system of units, the first decision in metrication, strict use of the SI system would cause the use of very unwieldy numbers in many areas of the highway field.

(3) Metrication of specifications and standards must start before other metrication activities can commence. These take an extremely long time.

(4) The method chosen ("soft" conversion, "hard" conversion, or "metric rethinking") for individual standards and specifications must reflect changes in other specifications and demands of consumers and supplies here and abroad. In general, most highway standards lend themselves readily to "hard" conversion.

(5) Actual costs of product metrication in nearly all instances were nowhere near that originally predicted,

(6) Beyond revision of specifications and standards, the major national problem germane to highways will be the conversion of highway signs.

8.2 State Agency Level.

(1) There is a definite need for a metrication organization within highway agencies.

(2) Revision of agency specifications and policy in coordination with national specification revisions will be the major task of the highway agency.

(3) Converting highway signs will be the most costly task carried out by the highway agency. However, organized national and state programs employing some suggested cost saving measures hopefully will keep the total cost below some of the predicted amounts and spread it over several years.

(4) One requirement common to the metrication of nearly all units within the highway agency is the need for computer services. These could be for the revision of computerized records, the revision of computer programs now used as calculation aids, or use of the computers for doing calculations required for metrication. Coordination of these activities may be required to keep the computer services unit of an agency from becoming overburdened.

(5) Training programs should not be of great concern. Technical people can generally teach themselves and less skilled employees need to know very few metric units to do their jobs.

8.3 Planning, Location and Design.

(1) The major impact of metrication on surveying will not be in the area of highways but on national and state coordinate systems. True metrication in this area, which includes U.S.G.S. topo mapping, may take decades, however this should have little impact on the highway field.

(2) Metrication of aerial surveying and mapping for highways poses no great problems. Suitable metric plan scales and related contours will have

to be chosen. Revision of equipment will basically be reconversion back to the original design as nearly all of it is manufactured in metric.

(3) Metrication of field surveying will require guidelines for accuracy of measurements. This poses a problem since no metric unit is equivalent to the accuracy commonly used in the highway field. If the 360° circle definition is kept for angles, only major equipment effected will be leveling rods, chains and tapes. Rods can be adapted but chains must be replaced. The problem is not that metric surveying equipment is unavailable but that the exact equipment desired may not be available when needed.

(4) The greatest impact of metrication on location and design will be in the area of design software. Design policy and design aids (computer programs, charts and graphs, and standard drawings) will have to be revised. The major problems are coordination with national standards and policies which will not change quickly and the amount of man hours and computer hours required. Replacement of equipment should be a relatively minor matter.

(5) Metric design without proper aids, specifications and hardware is difficult, time consuming, and frustrating.

(6) Preparing metric plans will require guidelines regarding scales, stationing, dimensioning, and paper size. This is not a difficult task. Once a market is available procurement of scales, curve templates, and linens should be no problem. These can be obtained now, but not in the quantity needed. Replacement or alteration of copying machines and files may be necessary.

(7) With regard to training, most design personnel can educate themselves when required if given suitable information. Surveyors may require a brief demonstration of the new equipment; but then can be sent out to work with it and in general will adapt quite quickly. Designers and

engineers will take longer to adapt, because they require knowledge of and ability to use more units. However, working with the units will lead to familiarity.

8.4 Right-of-Way.

(1) Change of equipment is almost negligable, for only scales will be required for all areas.
(2) Metrication of right-of-way design would be simple requiring only minor revision of computer programs.
(3) Metrication of right-of-way appraisal will require revision of manuals. This will be a large task in those sections relating to "replacement cost" methods of appraising.
(4) The main problem caused by metrication in the area of property acquisition will be its effect on interaction of the agency with property owners and the courts.
(5) Training of personnel in most instances should be negligable as the only two units of note are the metre and hectare.

8.5 Construction.

(1) Problems in metrication of project layout are the same as those in field surveying for design, with the additional requirement that layout personnel be made aware of the desired accuracy of measurement.
(2) Contracts will require some type of clause allowing substitution of American materials for metric materials that were supposed to have been available but were not, at the time of construction.
(3) Preparations of bids and estimates for metric projects require revision of calculation aids used and price quotes in metric units. Neither should be a major problem.
(4) Adaptation of larger construction equipment to meet "hard" converted specifications should not be exceedingly difficult and very little of the contractors' equipment should have to be replaced.

(5) Inspection for metric projects requires only minor changes; among them are the revision of inspection manuals and documentation forms and the purchase of rules and tapes for measuring.

(6) The major problem common to all material suppliers is the coordination of supply and demand. This can basically be handled only by coordination of conversion timetables. The degree of difficulty the supplier will have in converting depends on the equipment replacement requirements dictated by specification changes. In general, however, suppliers of bulk materials will have less difficulty converting than suppliers of fabricated materials.

(7) Metrication of testing procedure and equipment requires prior metrication of material specifications. Once this is done conversion of procedural manuals and forms should not be difficult. Changes of equipment will most likely require converting larger devices and replacement of smaller devices. The problem will be getting the necessary equipment when it is needed.

(8) In all instances, training of personnel should be no problem if necessary software and hardware are available.

8.6 Operations.

(1) The major problem (at least the costliest) for all highway agencies is traffic control, or to be more specific changing signs. Many policy changes will require changes in laws and in turn changes of signs. The actual "erection" of these signs would be a monumental task for just one unit of the highway agency.

(2) Conversion of road inventories from mileage-log basis to a kilometre-log basis and the concurent hardware changes necessary will be a large task in itself. Conversion of the actual record itself would turn this into a most difficult and time consuming procedure.

(3) Repair of customary American items on highways will be a problem not only during transition but also after metrication is completed. Use of adapter devices and salvaged material should help defray the costs of carrying dual stocks for long periods of time.

The one basic conclusion that can be derived from all the above is that metrication activities from top to bottom must be well planned and coordinated. No one area can metricate its operations without affecting some other area or requiring input from another. The "Alphonse and Gaston" argument of who shall go first has no place in metrication, we must all go together.

Chapter 9. Procedural Recommendations.

Based on the conclusions reached in Task 3, the following list of recommendations on procedure is submitted. The recommendations pertain basically to what should be done in the actual physical process of metrication. Recomendations for further work required to provide additional information as input to the metrication process will be discussed in Task 4.

9.1 National Level

(1) Passage of a national law which not only creates a National Metrication Board (Agency) but also makes metrication mandatory and gives the agency legal power to enforce its mandates.
(2) The system of units chosen with rules of application should be basically SI but allow use of non-SI metric units in special instances where no recommended SI unit proves to yield comprehendible figures to work with.
(3) Revision of national specifications and standards must be the first physical step in metrication.
(4) In revision of specifications and standards, do not attempt to apply the same metrication method to every case.

(5) For "hard" (rationalized) conversion, do not relax tolerances to allow substitution of the old customary American sizes during transition, except in special cases and then keep the time when this is allowed to as short a period as possible.

(6) Accurate coordinated timetables are a must and require coordination at a national level.

(7) Metrication of traffic signs must be directed on a national level. The use of dual signing systems is discouraged. It is recommended that a switch from strictly customary American to strictly metric should be made as fast as possible. The recommended method to accomplish this at the least cost and yet spread out costs over time is as follows: For a specified period of years replace all worn out customary American signs with metric signs. A customary American overlay will be placed over the metric sign. At the end of this specified time period customary American overlays will be removed and metric overlays placed on those customary American signs still left.

9.2 State Agency Level

(1) Public information programs are essential. The public must be made aware that changes will occur and must be educated in the correct units. However, a large part of this public education can be handled better by means other than those at the disposal of the highway agency.

(2) Within any transportation agency a metrication chief is a must. His full time should be devoted to metrication activities, and he should be directly responsible to the head of the agency.

(3) Each unit and subsequent sub-unit within the agency should have a metrication officer to form the chain of command. The percentage of time devoted to metrication activities by these metrication officers will be determined by necessity.

(4) Regardless of location within the chain of command, work involving revision of agency specifications, conversion of signs, and computer services required by metrication should be directed by the agency metrication chief.

(5) For educational purposes, the procurement of proper metric references is essential. However, elaborate teaching programs are not necessary. The best procedure is to: Give personnel the metric software and equipment they need to do the work; give them a short introduction to the units required; and then let them work. Do not over-train and do not train too early.

(6) Do not attempt metric work until metric software and equipment is available.

(7) To the greatest extent possible avoid moving personnel back and forth between metric and customary American jobs during transition.

(8) Do not attempt pilot programs for the sole purpose of educating employees. Pilot projects should be used to study the problems of metrication, to devise solutions and to analyze cost requirements. To be of value, they must be thoroughly documented in all aspects so that upon completion the information can be used to establish proper procedures for metrication of that particular phase of highway work.

9.3 Design and Plan Preparation

(1) Plans should not be dual dimensioned at any time, including the transition period.

(2) The 360° definition of a circle should be used in highway work with the degree subdivided into decimals of a degree, not minutes and seconds.

(3) Centerline stationing should be at 100 metre intervals with staking and cross-sections at 20 metre intervals.

(4) Use the 100 metre arc definition of degree of curvature.

(5) Profile elevations should be given every 20 metres on grade and at 5 or 10 metre increments for vertical curves depending on the "sharpness" of the curve.

(6) The use of the "plus" in stationing should be continued.

(7) All cross slopes and longitudinal grades should be given in percent or metres per metre except for earth slopes. Here the use of ratios (e.g. 2:1, 4:1, 8:1) should be continued.

(8) Use only metres and millimetres in dimensioning. Do not use only one unit on plan pages (such as bridge details all in millimetres), but use the decimal point as the unit indicator (e.g. 9.80 is 9.80 m and 980 is 980 mm).

(9) Use of plan scales other than the 1, 2, 5 x 10^x series is recommended (e.g. 1:4 and 1:400 help fill the large gap between 20 and 50 and 200 and 500).

(10) Litre is the recommended unit for liquid volumetric measurement.

9.4 Right-of-Way

(1) Existing right-of-way records and recorded instruments should not be converted all at once but when they are used.

(2) Do not dual dimension right-of-way plans and instruments.

(3) Hectare is the recommended unit for area in real estate, and should be given to three decimal places.

9.5 Construction

(1) During transition, metric construction contracts and/or plans should carry a clause allowing substitution of customary American products for metric products with permission of the agency where the metric products are not readily available.

(2) All measuring devices on the site (contractor and agency) should be strictly metric, not dual scale.

9.6 Operations

(1) Kilometre per hour is the recommended unit for speed limits.

(2) Speed limit signs should show the metric speed limit in a red circle to distinguish them from the previous customary American speed limit signs.

(3) Speed limits should be given in multiples of 10 kilometres per hour.

(4) Maintenance records should be converted from a mileage-log basis to a kilometre-log basis. The actual record itself need not be converted until it is used or normally revised, unless the change in the records system to accommodate records in both systems of units is a greater effort than converting the records themselves.

TASK 4

Program for Research

Chapter 1. Introduction

This metric research project was conceived and executed with the view that it was a "pilot" project into the problems of highway metrication and that additional research was needed to develop detailed plans for complete metrication of a highway department/division. The primary objectives of TASK 4 of this project are as follows:

a. Prepare a detailed plan for research aimed at solving conversion problems.

b. Develop a detailed plan for research needed to support a smooth and effective conversion from the English to the SI measurement system in various phases of highway operations (planning, layout, construction, traffic control, maintenance and inventory).

In TASK 1 we have learned how other nations have accomplished metrication and have obtained various views on metrication within the United States. In TASK 2 we have analyzed the Ohio Department of Transportation's (ODOT) work on three pilot metric projects, the dual unit destination signs and the motorists' and public's reaction to ODOT's program. In TASK 3 we have discussed the impact of metrication on highway work. After completion of TASKS 1, 2, and 3 we are now of the opinion that the need for future "pure" research is limited, but there is a great need for research into how metrication of major areas of highway work should be accomplished. The following chapters will discuss these major areas and will include suggestions concerning the need for further study in each area.

Chapter 2. National Effort

A study should be undertaken immediately at the national level to establish a national metrication timetable. The study should include all major areas requiring metrication in this country including, but not limited to: formal education, transportation, consumer products, national defense, construction industry, manufacturing, national standards and specifications, and legal documents. This national timetable should intertwine all functions so that the areas that must be metricated first will be completed on time to enable functions which depend on them to complete their metrication.

After the national timetable for metrication of the major areas has been completed a timetable for metrication of the principal elements for each area should be formulated. These individual timetables would delve into the "nuts and bolts" of each area and establish the starting and completion dates of each element to enable the completion of the metrication of the major area within the time frame established by the national timetable. Of course, the metrication board should coordinate closely with public and private organizations, including those actually involved in the areas of concern, to establish these metrication timetables.

Research in this area is needed to determine the effects each major area has on the other major areas and where each fits into the overall timetable. Working from the information we have provided in this report, and from information available from other metrication research projects and from other countries that have metricated, we believe a three to four month concentrated study could produce the necessary national timetable. Another three to four month study, after completion of the national timetable for all the major areas of concern should produce a timetable for each of the major areas, establishing the schedule for metrication of each principal element in the area. The study into the timetable for each of the major areas should be assigned to separate study groups, each group working on their parallel efforts

with every other group. These studies should be under the jurisdiction of the national metrication board with the chairman of each group being an official of the NMB.

The final step should be the establishment of a timetable for every component part of each element of the major areas and the formulation of detailed plans to accomplish the metrication as scheduled by the timetable. This effort would take nine months to one year to accomplish and could be assigned to various research agencies such as universities and private research organizations and foundations. The remainder of this task will take one element (highway metrication) of a major area (transportation) and outline our recommendations on how the studies into the metrication of the component parts of this element should be accomplished and what detailed plans should be the end result.

Chapter 3. Metrication of the Transportation Industry

The national study should establish what elements will be considered part of this area. Certainly, the highway mode, the aviation mode, the railway mode, the trucking industry and the maritime and inland shipping industry would have to be included. The intraeffect of each element with every other element will have to be determined as well as the intereffect of this area with the other major areas. The Transportation Industry, drawing its support from other major areas such as construction, manufacturing and specifications and standards, would most likely be one of the last industries to completely metricate. However, a high degree (80% to 90%) of metrication could be obtained in five to six years, based on the experience of the United Kingdom.

Chapter 4. Metrication of the Highway Mode

The metrication of this element of the major area, Transportation, should be further broken down into component parts. Each component part is interdependent on all of the other component parts and it will be vital for the study into this element to establish the interworkings of these components. These component parts would include:

a. Administration
b. Standards and Specifications
c. Planning
d. Design
e. Right-of-Way
f. Construction
g. Operations

The study into the metrication of the above components should result in a detailed plan of how to actually accomplish the changeover, when each component part should be metricated and how each component part affects the other components.

4.1 Recommendations

Having reviewed a substantial amount of information on highway metrication in Great Britain, Australia, New Zealand and other countries; having corresponded with all states and many agencies and organizations within the United States; and having been intimately involved in Ohio's five phase metric work program, we recommend that the next phase in the study of highway metrication should be in the following directions;

a. A limited amount of research in the formal sense of the word, but a continuation of the experiments started by Ohio's five phase metrication program by designing and constructing several more highway projects using the SI. These projects should be of a different type than the three Ohio projects, involving more complex design and construction problems with at least one project in an urbanized area. An attempt should be made to involve different locations in

the United States. These projects will increase our first hand experiences with highway metrication by involving different designers and contractors; and will act as a superb on-the-job experimental program. Many of the people involved in these projects would become leaders of metric activity in their states.

Our information has contained several loose statements concerning the temporary loss of efficiency, the duration of this loss, and extra costs associated with efficiency losses. In view of these statements, we need more first hand answers to these questions, under local conditions, to permit us to properly plan how to train personnel to alleviate this loss of efficiency.

These projects must be well planned and well documented to accomplish the above purposes. They should be totally metric projects not partially metric projects. Time and cost to metricate necessary hardware and software to do the actual project work should be completely documented. The actual work on the project in the metric system should also be completely documented.

The wider our data base is, the better understanding we will have on cost behavior. This is not a proposal for an econometric study; it is, rather, to point the future work in a direction which is useful for several purposes.

b. The other three phases of Ohio's metrication program (signing, public information, and motorists and public reaction) should also be continued but exercising great care against an overkill. This is a nation of businessmen, and businessmen do arithmetic very well. We should not baby the public with too much silk-coated information, surveys, brochures on the history of the metric system, etc., but provide them with facts on how metrication will affect their jobs and their everyday lives. Apparently, most people do not care if the United States is the only major industrial country in the world not on or in the process of converting to the metric system; they do not care that

metricating will favorably affect our national balance-of-trade situation. Many people think of metrication as the result of "foreign influence" of which they want no part. We need to extol the advantages of the metric system and throughly explain that the long range benefits of metrication will far outweigh the short term costs and inefficiencies.

We should by all means continue erecting dual-unit destination signs containing dual units and single metric messages at selected locations. This activity should be used to experiment in the best ways to present the metric message to the traveling public and to obtain motorists' reactions to the various experiments. Additionally, this activity should include a study of the methods used to accomplish the conversion, such as overlays or entirely new signs; the costs in material and labor; and the time it takes to erect (or convert) a given number of signs. This kind of information will permit highway departments to better plan the changeover and allocation of funds.

c. Develop real plans for the metrication of at least one actual agency with known human and material resources. It would be better to do this for two state highway agencies, one large and one small. These should be a detailed serious plan not just a general outline. The plan should be based on the following criteria.

1.) Metrication will occur country wide.
2.) The work involved will be done with present staff to the largest extent possible.
3.) Recommendations in this report will be the general rules.

The plans should include but not be limited to:

1.) Managerial setup for metrication.
2.) <u>Complete</u> inventory of staff specifying the amount of metric information they will be required to know to do their jobs.
3.) <u>Complete</u> inventory of hardware specifying what must be changed and whether it can be modified or must be replaced.
4.) <u>Complete</u> inventory of software specifying those whose revision depends on external factors and

those which can be internally changed. (Short case studies could be done in these areas to estimate time and cost required to revise these items).

5.) An estimated timetable for basic activities.

6.) Budgetary calculations based on factual information.

Further details regarding these items will be discussed in following sections. Advantages of the above versus "more research" are as follows:

1.) The plan will involve doing what will eventually be required anyway.

2.) Having a real department to deal with will avoid the pitfalls of generalized planning guidelines built on insufficient experience.

3.) Having developed a plan will enable the writing of a more specific planning guide.

d. Rather than developing educational materials for training of personnel, prepare a bibliography of recommended reference materials on the metric system that have already been developed or are in the process of being developed. Take advantage of what has been done by other countries such as Great Britain, Australia and New Zealand, who have converted from Imperial to metric units. Do not get into any extensive studies on teaching methods but use time and money to compile references. If the experience of others is any criteria, the teaching method is nowhere near as important as the reference material.

In general allow public education to be handled by those agencies more proficient in that area. Highway agencies should direct their efforts in this area to supplying input to educators regarding what the motorists will need to know to drive on "metric" highways and in continuing programs such as the selected dual-unit destination signs.

e. An in depth study of the legal considerations of highway metrication should be undertaken. We have just briefly touched upon this issue in TASK 3, highlighting

the obvious but going into no detail. A detailed inventory of national, state and local laws that will be affected by highway metrication is required.

4.2 Administration

The primary needs for "research" in the administrative areas of highway metrication concern training, public information, coordination of metrication activities, and budgeting. Needs in these areas are more information gathering than pure research. We have briefly touched upon some of these programs but will go into more detail in this and following sections.

Before "training programs" can be developed additional information is required in two areas. First a complete detailed list of highway agency position descriptions must be prepared. This should include the location of the position within the agency, the position's job description, required qualifications, and necessary metric information required by metrication of the job. This can be prepared using one or two states as a sample to avoid duplication of effort. Titles specific to the "model" agencies should be avoided, with the job descriptions and qualifications used as the major definitions of the jobs. A bibliography of recommended metric reference materials should then be developed with suggested references to be used in the education of various categories of employees.

Research in the area of public information in general should be left to education fields, with the highway mode supplying input. One area where more research should be done is that of informational highway signs. A continuation of the type of research in Phase 3 of Ohio's Five Phase Program would be desirable in other areas of the country. This should include installations and study of dual-unit destination signs placed on highways other than interstates, especially in more heavily signed areas, to determine their usefullness as an education tool in other areas. The dual-unit signs on Ohio's interstates appeared to have educational

value and further efforts are needed to determine the value of these signs in other locations.

Before any serious planning of metrication activities can be done large amounts of information must be compiled. One area which deserves further attention is the equipment used by highway agencies. A detailed inventory of this equipment (from paper and scales to large equipment) is required. It should specify what will and will not be affected by metrication. For those items effected, it should be specified whether the item can be adjusted or has to be replaced and what the desired metric equipment should be. Additional information is also required regarding suppliers of this equipment (for example who the major suppliers are in given areas? What metric equipment they now provide or can provide? What are their plans for metrication? And what will be required to provide desired equipment?)

Although the following items will differ for individual agencies, more information is needed regarding the actual amount of work required for printing software and the computer requirements for metrication. These are common problems of all component parts of the highway agency, and the total requirement will necessarily be large, even though the requirements for individual units may be small.

4.3 Standards and Specifications

The primary thrust of research in the area of software changes should be focussed in two directions. First it must be determined what are the critical national standards and specifications for the highway mode. These are the ones which are used by many other agencies "down the line" as parent specifications, or adopted outright and any delays in revision of them will delay metrication for all. These will be the specifications and standards that must be revised first. Along with this it would also be desirable for each specification writing agency to prepare a list of interacting specifications so that when one is revised the effect on others can be immediately checked. Although this last

suggestion is not purely research, being an in house problem and bordering on the actual work that must be done; it nonetheless can be done before metrication activity takes place and will reduce the work required later. It also should reduce the chance of any errors such as Great Britain made with sieve sizes and percent passing specifications.

Second and just as important is the need to determine the type of metrication that should be applied to various highway materials, which was touched upon in TASK 3. A complete list of materials used in highway construction is required. Pertinent information for each material would be; the relative amount used by the highway mode in comparison to other consumers, the desired change for highway metrication, and the impact of various types of metrication on the producers. This is a large task and each element would be a study in itself. A suggested plan for this work is given below, with a timetable shown in Figure 25.

1) Prepare a highway material list.
2) Determine proportion of use by highways.
3) Determine impact of types of metrication on materials of which highways are a major user.
4) Determine type of metrication desirable or tolerable to highway mode for these items.
5) Make recommendations to specifications writers on those items.

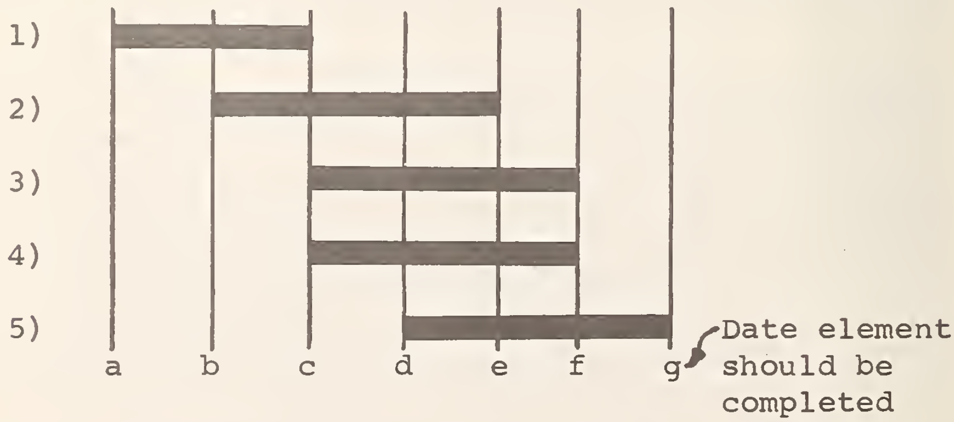


Figure 25. Suggested Timetable Form

Various tasks could be performed by different organizations but they would have to be coordinated by one.

4.4 Highway Planning

Although it appears that highway planning will not be greatly affected by metrication in comparison to other parts of the highway mode, the little bit of information obtained during this study that was relevant to this area cannot be used as a guideline. The literature and the British had little to say about it; and the Ohio pilot projects were basically relocation projects and began metric work only after the route location had been determined. Further pilot projects should include planning and location as part of the metric work. How metrication affected this area should be well documented including what had to be done, what did it cost and how long it took.

4.5 Design

Although this area was covered to a large degree in TASK 3, nonetheless there still remain many things that must be determined. Since revision of policy and design aids will be the major problem for this area most of the recommendations for further study pertain to this area.

As with specifications a study should be conducted to determine what national policy and aids are extensively used by state and local agencies as bases for their manuals. When actual metrication begins these would necessarily be the first to be revised. Additionally, the policy itself should be examined especially in the area of accuracy of measurements and detailing. In the past this has generally been to the tenth of an inch or a hundreth of an inch. Individual cases should be examined to determine if there is a valid reason to retain this accuracy which was nominal in the American system but not in metric. It should be determined where relaxing the accuracy to the nearest nominal metric unit can be allowed without any substantial reduction in the quality of the end product.

As mentioned previously in Section 4.1 it would be desirable to obtain well documented information regarding the actual time and costs involved with the physical revision of these aids.

Although it might seem to be a minor item, selection of the format for paper should be done carefully. The "A" series has been recommended by many, however, there are other series for metric paper. The basic point of interest here is not how the size works for highway plans (A1 worked well for these in both Britain and Ohio), but how the paper size affects copying machines and files. Some research should be conducted into the effects metric paper formats have in this area.

4.6 Right-of-Way

Additional information is required for right-of-way in the area of appraising. The information given in this study is based on only one experience using only one method of appraisal in both systems for a rural area. Further pilot projects should do appraising in only metric and also examine other methods of appraising beyond the approach used on the PER-188-03.84 project (Metric Project No. 3).

Further study should also be conducted with regard to negotiators discussing the metric system with property owners. Emphasis should be placed on whether this is a useful way of exposing the public to the metric system and to what extent the negotiator should discuss the metric system, if at all. Of primary interest here are the negotiators ability and desire to discuss the metric system with the property owner and the property owner's attitude to any information presented him under the circumstances that his property is being "taken" from him for highway Right-of-Way.

4.7 Construction

As one of the major concerns of highway builders will be adaptation of present heavy equipment to build metric projects, additional information should be obtained concerning this equipment. The two main tasks should be to

examine the equipment itself and to obtain information about suppliers. One type of information required for equipment is basically how changes in highway dimensions will affect the particular piece of equipment. Another is to what extent the equipment can be adapted to meet new requirements. This is a necessary input to the determination of the revised metric standards used for highways and should be researched before standards are changed. We certainly do not wish to write standards that would require complete replacement of all heavy equipment used in road building.

With regard to heavy equipment manufacturers, inquiries were made in this study but, because of time limitations, not to the extent desired and without any followup for additional information. The primary information needed is who they are, what they supply metric now, what they plan to do metric, and, if so, how long do they plan to keep replacement parts for present equipment.

4.8 Operations

Additional information is required for the two largest problem areas of operations: signs and repairs. We now know enough to define these as major problem areas but not enough to really solve very many of the problems.

A study should be conducted on prima facie speed limits used by various states and local governments. The purpose should be to define a set of national metric speed limits for various highway locations based on multiples of ten kilometres per hour.

More in line with pure research is the need for an optimum overlay which can be used in the change of signs. Criteria for this overlay are listed below.

1) It must be reasonably inexpensive to produce and place on newly manufactured and existing signs.
2) It should be durable enough to last through the transition period proposed for highway signs.

3) It should be reasonably easy to remove from the sign without damaging the covered message.
4) It should be reasonably non-succeptible to vandalism.

These criteria seem to be quite stringent and the cost of pure research might be expensive. However, with the vast amount of signs which have to be converted the savings could be very large, paying for the study many times over.

At the end of the spectrum bordering the actual task of sign conversion is the preparation of sign inventories. This of course will have to be done by individual agencies. This should give sign locations and size along with the message for all signs requiring change. This may seem like a large task that could be done much later, but coupled with well documented data on cost of sign erection this is the only way we can ever get an accurate estimate of what sign changes will cost.

Also necessary will be information regarding sign life, if the program for conversion of signs is to employ the attrition period of signs to help spread out costs.

Further study is also required for the area of highway repair. Primary emphasis should be placed on determining what are the most common repairs made and how metrication of the products used will affect the repairs. The application of adapter devices should also be considered.

Chapter 5. Summary

This TASK has discussed the need for further research and study in the subject of highway metrication, with emphasis on studies. The discussion has mentioned national needs; and presented in detail state highway agency needs in the areas of administration, standards and specifications, planning, design, right-of-way, construction and operations. A summary of the most important recommendations follows:

1. Timetables
   a. A national timetable for metrication of all major areas in the United States should be established and issued posthaste. Research is required in this area to determine the effects each major area has on the other major areas and where each fits into the overall timetable.
   b. Individual timetables should be established for each major area as determined by the national timetable. In depth studies of the needs of each major area and the interactions of the major areas will be required.
   c. Timetables for every element and every component part of the major areas should be established after exhaustive studies. These studies could be accomplished by universities or private research organizations.

2. Standards and Specifications
   a. A study to determine what national standards and specifications are critical to the highway mode should be started as soon as possible. The most critical should be metricated first.
   b. The type of metrication (soft, hard or metric re-thinking) to be applied to various hignway functions and materials should be established to aid in the conversion of standards and specifications.

3. Inventory

   Research is required in this area to determine what products need to be metricated and to what extent. Determination should be made as to how long dual inventory will be required for various products.

4. Signing

   Research and study is required in this area to determine how the metrication of highway signs will be accomplished.

5. <u>Teaching Aids and Educational Programs For Highway Personnel and Users</u>

The need in this area is to develop teaching aids for use in instructing highway personnel and to determine the type and degree of training that should be given to each "class" of personnel.

Education programs (such as signing and public information) should be continued and expanded to all states. However, this effort should be limited to what the public needs to know to safely and efficiently drive the state's highways. Other metric educational matters should be left to those better equipped to educate the public such as schools, universities and state education agencies.

6. <u>Legal Impact of Metrication</u>

Research into the legal requirements that pertain to highway functions is a must. This research should cover, at a minimum, speed laws, contractural documents and real estate documents.

7. <u>Highway Projects</u>

Additional highway projects should be constructed to study aspects of highway metrication not covered in depth, or not covered at all, by ODOT's three metric projects. These should be <u>totally</u>, not <u>partially</u>, metric projects.

8. <u>Metrication of a Highway Agency</u>

Detailed plans for metrication of one or two actual highway agencies should be formulated as part of an in-depth study of highway metrication. These plans should include all phases of highway planning, design, construction and operation. This study could best be handled by a state highway agency.

APERCU

A vast amount of information has been given in this report. To aid the reader in grasping the salient points which have been presented in the body of the report, this brief discussion is offered. No attempt has been made to summarize each and every detail.

National Policies and Practices

A metrication law requiring the United States to convert to the International System of Units (SI) should be passed as soon as possible. A National Metrication Board should be established by the metrication law. Metrication is coming and proper preparation is required for efficiency. Coordination of all activities at a national level is a must. The purchasing power of the government can be used to encourage rapid metrication. A decision by the government not to subsidize metrication could result in ingenious methods by those directly involved to keep costs at a minimum. The government can collect and make known to industry all information pertaining to the demand for metric products.

State Agency Policies and Practices

Timetables for metrication, coordinated with all facets should be produced at an early stage. Management should make a decision, at an early date, on what method of metrication ("soft", "hard" or "metric rethinking") will be used for the various phases of highway administration, design and planning, construction and operations. A metrication officer with the power to make and enforce decisions should be appointed early in the metrication process. Metrication of computer services should be coordinated to prevent overloading of computer capabilities.

Legal Requirements

Laws should be studied to ascertain their effect on metrication. Special consideration should be given to speed limit laws and laws which now require use of imperial products.

Standards and Specifications

This is the most difficult and time consuming phase of metrication. National and State agencies should start the process of metricating standards and specifications immediately. Revisions will require input from all phases of highway work including design agencies, contractors, suppliers and manufacturers.

Metrication of Highway Design

Metrication of design poses no serious problems with proper planning. It is vital that metric design information (including specifications and standards) and measuring equipment (drafting and surveying) are available at an early stage. Care should be exercised in establishing tolerances, especially in the transition stage. Dual dimensioning should never be used. Strict use of the SI could lead to unwieldy numbers in the design stage. Use of scales for drawings, other than recommended SI series should be considered for special applications.

Metrication of Material and Equipment

Without careful coordination the metrication of material could be delayed due to an indecision loop, e.g. those responsible for the design of construction projects refrain from specifying coordinated metric components until they are certain that these are in production and will be available when required on the site. Dual stocking of materials, during the transition period, will probably be the greatest problem in this area. Therefore, the stocking of both metric and imperial sizes should be kept at a minimum. A problem in identifying metric and imperial parts and supplies will occur during the transition period; therefore, a marking system to identify metric supplies should be devised and used. Preferred metric sizes of key products should be decided after consultation with designers, manufacturing users, regulatory authorities and international standards. In most cases, heavy construction equipment can be modified, at relatively little cost, to do metric work until such time as the equipment requires replacement because of normal wear and tear.

Proper metric office equipment is essential to the successful operation of any progressive agency. It will be found that many pieces of equipment can be modified at very little cost. Two problems that may arise in metricating

office equipment could prove costly: (1) a changeover of filing cabinets and other office furniture to accept metric sized drawing sheets and office paper and (2) possibly a complete change in reproduction machinery necessitated by new paper sizes. Obviously, a well planned conversion program is a necessity to keep costs at a minimum.

Metrication of Construction

During the transition period construction should include some type of clause allowing substitution of customary American materials for metric materials that were supposed to have been available, but were not, at the time of construction. Preparation of tenders should be no major problem, requiring only a revision of the calculation aids used and price quotes. Proper indoctrination of personnel in the use of the metric system, procurement of metric supplies and equipment on time and careful checking of the work as it progresses should permit the construction of metric projects with little difficulty and with minor cost increases. These cost increases should disappear in a short time after the contractor, and his employees, have adapted to the metric system.

Metrication of Operations

Metrication of operations will only be feasible under a planned nationally coordinated program. Evolutionary metrication on the part of individual polities would cause chaos. Maintenance procedures would become ridiculous as it would be nearly impossible to get the right sized materials and parts all the time. Enforcement of traffic laws (speed) would be impossible with some areas posting metric speed limit signs and others imperial.

The second most difficult (second to metrication of standards and specifications) task, and probably the most expensive, to confront a highway agency is that of metricating its signs. This must be another well planned activity and should involve taking as much advantage as possible of a sign's physical "life". The physical appearance of the signs should be a national decision and they should "look different" from the signs now in use.

Maintenance of the highway during the transition period from all customary American units to all metric units may involve some problems in supplies and equipment. Use of

adapter devices and salvaged material should help defray the costs of carrying dual stocks for long periods of time.

Education and Training

Much information has been obtained on this subject. It all condenses to the following principles for training of employees:

(1) Train each individual only to the degree he needs to perform his job; do not overtrain.

(2) Train an employee in metrics as close to the time of need as possible.

(3) Provide each employee with all the metric information and equipment he needs, in advance of the need.

Education of the public through a public information program is worthwhile to inform the public of metrication activities. Public acceptance of the metric system is greater when they are more aware of the metric system and its relationship to the customary American system.

Costs and Benefits of Metrication

1. Costs.

The total costs of metricating the highway industry is impossible to pinpoint. However, it is certain that the total costs will be nowhere near the "nightmarish" amounts that have been predicted. Apparently, a fairly rapid changeover will reduce the total costs. The two areas of greatest cost will be that of standards and specifications and highway signs. The increased cost of constructing a highway due to metrication appears to be negligible. The primary costs, other than standards, specifications and signs, appear to be:

a. metrication of tools and equipment.

b. increased inventory (dual stocks) during the transition period.

c. training of employees.

d. loss of employee efficiency, both temporary and permanent.

e. metrication of computer services.

f. metrication of office "software".

2. Benefits

Most of the benefits, to a highway agency, resulting from metrication are intangible in nature. Among these benefits are:

a. the SI is essentially a practical system which has so great a simplifying effect as to render most short-cut procedures, as now used, unnecessary.

b. rationalization of standards.

c. reduction of component variety.

d. gain in employee efficiency in the long run (the permanent gain in efficiency should more than offset the one-time conversion costs).

Conclusions

One thread of thought can be seen throughout the preceeding discussion and that thought is that metrication activities must be well planned and coordinated from top to bottom at all levels of operations. No one area can metricate its activities without affecting some other area or requiring input from another.

As stated in the U. S. Department of Commerce's report to the Congress (1971), metrication is "a decision whose time has come". Our basic conclusion is that it is not a matter of whether this country will change to the metric system but a matter of when the change will take place.

To achieve this changeover to the metric system in the most efficient way possible, we offer the following recommendations.

Recommendations

1. The Congress of the United States should pass a law requiring this country to convert to the International System of Units (SI) within a given period of time. We recommend this time period to be ten years. The law should require mandatory conversion, not voluntary conversion, on the part of all facets of American life. This law should be passed as soon as possible.

2. The Congress should establish a National Metrication Board immediately, empowered to establish and enforce a national metrication timetable. This timetable should be issued as soon as feasible after input from and coordination with all levels of private and public agencies and organizations.

Disclaimer

The above recommendations, and all other recommendations contained in this report, are those of the authors and do not necessarily reflect the policy of either the Ohio Department of Transportation or the Federal Highway Administration.

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